Mars Reconnaissance Orbiter

High Resolution Imaging Science Experiment

Version 2.0

Experiment Operations Plan

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Related documents:

HiRISE proposal
HiRISE Experiment Implementation Plan
HiRISE Calibration Plan
HiRISE ATLO plan
MTT and PTF SIS documents
MRO Mission Plan
MRO Data Archive Plan

ACRONYMS AND ABBREVIATIONS

APGEN	Activity Plan Generator
AMMOS	Advanced Multi-Mission Operations System
ATE	Automatic Terrain Extraction
ATLO	Assembly, Test, and Launch Operations
CCD	Charge Couple Device
CCSDS	Consultative Committee for Space Data Systems
CDR	Critical Design Review
CFDP	CCSDS File Delivery Protocol
C&DH	Command and Data Handling
CO-I	Co-Investigator
CRISM	Compact Reconnaissance Imaging Spectrometer for Mars
CTX	Context Imager
DARWG	Data Archive Working Group
DSN	Deep Space Network
DTT	Data Tracking Tool
CCD	Charge Couple Device
CFDP	CCSD File Delivery Protocol
DEM	Digital Elevation Model
DMD	Data Monitor and Display Subsystem
DPI	Deputy Principal Investigator
DVD	Digital Versatile Disc
EAC	Educational Advisory Council
EOP	Experiment Operations Plan
E/PO	Educational and Public Outreach
EDR	Engineering Data Record (raw science data product)
EOM	End of Mission
FEI	File Exchange Interface
FELICS	Fast Efficient Lossless Image Compression System
FOV	Field of View
FTE	Full Time Equivalent
GDS	Ground Data System
HiCat	HiRISE Catalog and Data Base Management System
HiCommand	HiRISE instrument command load generator
HiDOg	HiRISE Downlink Organizer
HiEST	HiRISE Engineering Support Team
HiPlan	HiRISE Target Planning Software
HiProc	Image Processing Engine for standard data product generation
HiRISE	High Resolution Imaging Science Experiment
HiROC	HiRISE Operations Center
HiSYS	HiRISE Systems Group (controlling authority for HiRISE MOS/GDS planning)
HiWeb	HiRISE website for submitting image suggestions, browsing, analyzing, and distributing HiRISE products
Hz	Hertz
IDL	Interactive Data Language
IPTF	Integrated Pointing/Target File

IO	Interactive Observation
IS	Investigation Scientist
ITL	Integrated Target List
ISIS	Integrated Software for Imagers and Spectrometers
JPL	Jet Propulsion Laboratory
LMA	Lockheed Martin Aerospace
LUT	Lookup Table
MEP	Mars Exploration Program
MGS	Mars Global Surveyor
MOC	Mars Orbiter Camera
MOS	Mission Operations
MRO	Mars Reconnaissance Orbiter
MRO_HIRISE_SIM	HiRISE Instrument Commanding Tool developed at Ball Aerospace
MTT	Mission Targeting Tool
MySQL	Data Base Management System
NAIF	Navigation Ancillary Information Facility
NIFL	Non-Interactive File Load available through GNU general public license
ORT	Operational Readiness Test
PDR	Preliminary Design Review
PDS	Planetary Data System
PI	Principal Investigator
PIP	Proposal Information Package
PIRL	Planetary Image Research Laboratory
POST	Payload Operations Support Team
PSF	Point Spread Function
PSG	Project Science Group
PSP	Primary Science Phase
PTF	Payload Target File
RDR	Reduced Data Record (radiometrically and geometrically processed images)
RSDS	Raw Science Data Server
S/C	Spacecraft
SIE	MRO Sequence Integration Engineer
SEQGEN	Sequence Generator
SOCET SET	Softcopy Exploitation Toolset (digital stereogrammetric tool)
SPICE	Spacecraft and Planet ephemeredes, Instrument, Camera Matrix, and Event kernels
SNR	Signal to Noise Ratio
SSR	Solid State Recorder
ST	Star Tracker
SVT	Sequence Verification Test
TDI	Time Delay and Integration
TAG	Target Acquisition Group
SOPC	Science Operations and Planning Computer
SOWG	Science Operations Working Group
UA	University of Arizona
USGS	United States Geological Survey

1 PURPOSE AND SCOPE

The HiRISE Experiment Operations Plan describes how the HiRISE investigation will be carried out, primarily in Phase-E (starting October 1, 2005) but also including some discussion of efforts needed in Phase C/D. This EOP covers operations until the end of the Primary Science Phase (PSP) plus 6 months to complete data processing and archival. It does not cover operations during the Relay Phase or extended missions. Its scope covers the HiRISE team's plan for acquisition and analysis of data to meet our science objectives, from the development of long range plans, through sequence production, to data acquisition, analysis, and archival. It includes uplink support for candidate landing sites of future missions, but does not support DEMs or other special products for landing site evaluations. The staff, ground data system, and facilities needed to carry out this endeavor are described.

A brief history of and future plans for the EOP-development effort is provided in **table 1.0**

Table 1.0 – History of and future plan for EOP development	
History	
Date	**Description**
Summer 2002	First EOP writing workshop
Sep 15, 2003	Preliminary EOP delivered
Oct 15, 2002	Power supply descope: operation of >10 CCDs not assured
Jan 10, 2003	HiRISE MOS/GDS Peer Review at UA RFAs developed in 9 summary areas. Comments and responses are attached in **Appendix G**
Dec 2002 - Feb 2003	Phase-E funding negotiations; funding needs estimated in 9/15/02 EOP cut ~10%
Feb 3, 2003	HiRISE Calibration Review at Flagstaff
Feb 11-13, 2003	MOS/GDS PDR at Pasadena
Feb 22, 2003	HiRISE Instrument CDR at Ball
May 20-22, 2003	MRO CDR at Pasadena
Jun 19-20, 2003	HiTECH meeting at Flagstaff, decision to go to ISIS 3.0
Jul 9, 2003	SEAKR CDR – new decompression software task for HiROC
Jul 17, 2003	ATLO kickoff meeting at LMA, Ball ATLO plan prepared
Aug 15, 2003	Meeting with PDS and others at UA on PDS Data Node for HiRISE
Aug 18-20, 2003	EOP writing workshop at Flagstaff
Future Plans	
Sep 18, 2003	PDS Peer Review
Oct 1, 2003	Deliver revised EOP to project
Oct 7, 2003	Meeting of HiTECH and HiSYS groups at ASU with THEMIS team to discuss adaptation of MTT tool for HiPlan.
Nov 14, 2003	HiRISE MOS/GDS Peer Review at UA
Feb 2004	Project MOS/GDS CDR

1.1 HiRISE Science Objectives

The HiRISE science goals are to investigate a wide range of geologic and climatic processes, with emphasis on distinguishing between deposits and landforms resulting from aqueous, eolian, volcanic, or other processes. The instrument is optimized for these objectives and for the evaluation of landing sites. The camera will provide an unprecedented combination of spatial sampling (25.5 -32.0 cm/pixel pixel in primary science orbit) capable of detecting meter scale objects on the surface, signal-to-noise ratio

(>100:1 at all latitudes), swath width (5 - 6.4 kilometers), color (1 - 1.3 kilometers swath), and stereo coverage (see **table 1.1a**). The Level-1 science requirements are listed in **table 1.1b**.

Table 1.1a – Science Capabilities

Science Feature	Capability
Ground Sampling Dimension	30 cm/pixel (at 300 km altitude)
Swath width (Red bandpass)	6 km (at 300 km altitude)
3-Color swath width	1.2 km (at 300 km)
Maximum image size	20,000 x 65,000 pixels
Signal/Noise Ratio (SNR)	>100:1
Color Bandpasses	Red: 550-850 nm Blue-Green: 400-600 nm NIR: 800-1000 nm
Stereo topographic precision	~20 cm vertical precision over ~1.5 m^2 areas
Pixel binning	None, 2x2, 3x3, 4x4, 8x8, 16x16; each CCD separately commanded.
Number of TDI lines	128, 64, 32, 8
Pixel type (bits per pixel)	14; can be compressed to 8 bits via look-up tables (LUTs)
Compression (8-bit only)	Fast and Efficient Lossless Image Compression System (FELICS)

Table 1.1b - MRO Level 1 Science Requirements

- High-Resolution Imaging Science Experiment (HiRISE)
  - ◊ Ability to resolve 1-meter-scale objects and differences in surface morphology
  - ◊ Swath width greater than 3.5 km *(HiRISE has 20,000 pixels for 6 km swath width at 300 km altitude)*
  - ◊ Signal to noise ratio of order 50 to 1 or more (*HiRISE is >100:1 SNR*)
  - ◊ When required, stereo imaging is achieved using observations on different orbit passes.
- The MRO shall acquire data sets from 2 or more of its instruments for characterization of targeted sites, **including high-resolution imaging data needed to certify these sites with respect to landing site hazards and to support the planning of surface operations, including surface mobility.**
- HiRISE interpretation: Stereo-derived Digital Elevation Models (DEMs) with ≤0.5 m vertical precision are needed both to certify landing safety and to support planning of surface operations.

In addition to these Level 1 requirements, the HiRISE team has several other science requirements, such as the ability to: (1) distinguish color variations at high spatial resolution (<1 m/pixel), (2) image the surface under twilight illumination via pixel binning, and (3) acquire lower-resolution context around high-resolution strips via pixel binning.

Landing site characterization requested by the Mars Exploration Program (MEP) is supported in the uplink process but data analysis is not included in our Experiment Operations Plan. Landing site locations will be identified by MEP representatives at the Target Acquisition Group (TAG), and HiRISE images of these sites will be integrated into timelines and sequences through the process described in

section 6. Landing site images acquired for MEP will be processed to the level of standard Reduced Data Records (RDR's) but further processing (such as DEM production) is not within current budget plans.

1.2 Operational Overview

The HiRISE investigation will be executed in the distributed operations architecture typical of previous Mars Orbiter missions. In the distributed architecture the science instrument teams operate their instruments from remote sites at their home institutions. The HiRISE Operations Center (HiROC) will be located at the PI's institution, the Lunar and Planetary Lab at the University of Arizona, Tucson.

Desired observations and specific science objectives are defined by the HiRISE team, in collaboration with the Mars science community. Instrument operations will be planned by the HiRISE team. Observational timelines and camera commands will be developed at HiROC. The project will furnish a secure line, a Science Operations and Planning Computer (SOPC) and software for transfer of instrument commands to JPL for radiation to the spacecraft.

Likewise data is transmitted from JPL to HiROC for all data processing. The HiRISE ground data system must support receipt of up to 9.1 Tb of raw image and engineering data during the PSP, lasting 2 Earth years. All images are cataloged and processed at HiROC. Co-Investigators and other MRO and MEP scientists will pull the images they plan to analyze from the HiROC image database. The HiRISE team is responsible for ultimate delivery of archival quality data to the PDS. During the active phase of the mission HiROC may be a PDS HiRISE Data Node (pending negotiations with the PDS). The HiRISE team is responsible for monitoring the health and performance of the instrument.

HiRISE observing strategies include: (1) planning "interactive observations" (IO's), coordinated with other MRO experiments and S/C operations through a coordinated effort involving the Target Acquisition Group (TAG) and Science Operations Working Group (SOWG); and (2) acquiring nadir-viewing observations, which are considered non-interactive although we may coordinate these with CRISM and/or the Context Imager (CTX). Our nominal plan is to acquire approximately 10,000 observations involving hundreds of full-resolution 20K x 40K pixel images and thousands of high-resolution sub-scenes with ~1 meter/pixel context. We will acquire ~1000 stereo pairs, and a subset of these are be used in the production of Digital Elevation Models (DEMs). Repeat coverage for active processes will be acquired throughout the mission.

The HiRISE instrument offers a wide range of operating modes used for tailoring observations to meet specific science objectives, viewing conditions, and operating constraints. The focal plane houses 14 CCD detector arrays of 2048 (crosstrack) by 128 (downtrack) detectors for Time Delay and Integration (TDI). At least 10 CCDs can be simultaneously operated. Each CCD can be independently commanded. Ten CCDs form the red channels (20,000 non-overlapping pixels) and two sets of CCD pairs form the blue-green and near infrared color channels (each with 4,000 non-overlapping pixels). The CCDs are commanded with a TDI line transfer rate, pixel and line binning (1, 2, 3, 4, 8, 16 pixel binning), use of LUT tables for conversion from 14 to 8-bit pixels, number of TDI integration lines (8, 32, 64, and 128), and number of lines in an observation (up to 65,000 unbinned lines). The HiRISE instrument will make use of the FELICS (Fast and Efficient Lossless Image Compression System) data compression hardware.

1.3 HiRISE MOS/GDS Requirements Summary

There are two general drivers on the design and operation of HiROC: (1) requirements described in the Announcement of Opportunity and Proposal Information Packet, including MEP's distributed operations architecture; and (2) the HiRISE Team goal for distributed operations at Co-I institutions. **Table 1.3** summarizes the high-level functional requirements for HiROC.

Table 1.3 - High level requirements for the HiRISE Operations Center
Data Observations and Volumes
Target 10,000 observations during PSP
4,000 Interactive Observations (single views)
1,000 Interactive Targets in stereo (2,000 Images)
4,000 Non-Interactive (nadir) observations
Acquire, downlink, and process 9.1 Tb of instrument science data during PSP
Acquire instrument calibration observations during cruise
Observation Planning and Uplink
Develop Interactive Observations
Participate in quarterly PSG/TAG meetings to define "must have" targets
Participate in 28-day cycle TAG planning
Develop Non-Interactive (nadir) Observations
Nadir observations planned weekly
Observations coordinated directly with other Instrument teams
Maintain a Database of Suggested Images
Suggested images identified weeks, months, and years before observation
Mars Investigators and public participate in identifying suggested images
Develop and maintain a database of all uplink operational events
Downlink Data Processing
Receive and catalog downlink data obtained from MRO GDS
Automate data processing for standard data product creation
Verify and Validate standard data products
Develop and maintain a database of all downlink processing and operational events
Data Access to Science Team, MRO Project, and Public
HiRISE products available to Science Team and MRO investigators within weeks
HiRISE products available to general public on best effort basis
HiRISE products available through web-based system
Archive Preparation and Distribution to PDS
HiROC supports PDS as a MRO HiRISE Data Node (pending negotiations with PDS)
Hardmedia deliveries provided to PDS delivered on a schedule defined in the MRO Data Archive and transfer plan.
Participate in DARWG
Develop PDS interface agreements & SIS documentation
Monitor Instrument Performance and Health
HiROC and Ball Aerospace conduct routine instrument health monitoring

Monitoring of engineering stream through all mission phases
Alarm system alerts HiROC staff when instrument operational limits exceeded
Ball engineers on-call to lead anomaly resolution and generating special camera commands
Engineering database at HiROC immediately available to Ball engineers
Weekly anomaly reports prepared for Science Team (Ball responsibility)
Six Month Performance Reports prepared for Science Team (Ball responsibility)
Science Data Analysis
Science analysis and image processing carried out at Co-I institutions
Co-Is equipped with work stations to support data analysis
HiRISE image processing capabilities
Data Ingestion
Radiometric Calibration
Geometric Processing
Photometric Normalization
Color Merge
Cartography (mosaicking, map projection, c-smithing, tie-point control)
Facilities
Building Space - 4,900 sq. ft.
+Facility Security for HiROC
Computer Center operational safeguards (power, fire suppression)
HiRISE GDS Hardware
Host SOPC in a secure facility
Processing capability for 2x expected data volume
Uplink backup facility maintained at JPL
Maintain reliable backups of complete HiRISE datasets.
On-line storage capability of 178Tb
Meet interplanetary network directorate (IND) security requirements
Workstations hardware provided to each Co-I
Dedicated network link to MRO GDS equivalent to two T1 lines.
Training
HiROC staff participates in project-provided training
HiROC staff trained in HiRISE operations
HiRISE team trained in HiPlan and HiWeb tools
HiRISE team trained in data analysis tools using ISIS
Testing
Ball Aerospace and HiRISE Science Team participate in ATLO
HIRISE Team participates in Operation Readiness Reviews
Cruise
Instrument commanded to acquire cruise calibrations
Support radiometric calibration analysis
Support geometric calibration analysis
Instrument monitoring performed throughout cruise

2 PERSONNEL ROLES AND RESPONSIBILITIES

2.1 General

The HiRISE Phase-E team is shown in **figure 2.1**. The PI, Alfred McEwen, is responsible for the overall success of the HiRISE investigation and the point of contact with the MRO project. The Deputy PI, Candice Hansen, will have the authority to act for the PI and represent HiRISE whenever necessary. During Phase-E, Instrument Manager Alan Delamere will be the primary contact with the Ball engineering staff for HiRISE Engineering Support Team (HiEST). The manager of the HiRISE Operations Center (HiROC), Eric Eliason, will oversee operations, staff, and scheduling. The E/PO Manager, Virginia Gulick, will lead the HiRISE Education and Public Outreach activities. Ken Herkenhoff will lead the instrument calibration activities during all phases of the mission. **Table 2.1a** provides a science-staffing summary and **table 2.1b** summarizes technical and program development support for HiROC and science analysis software.

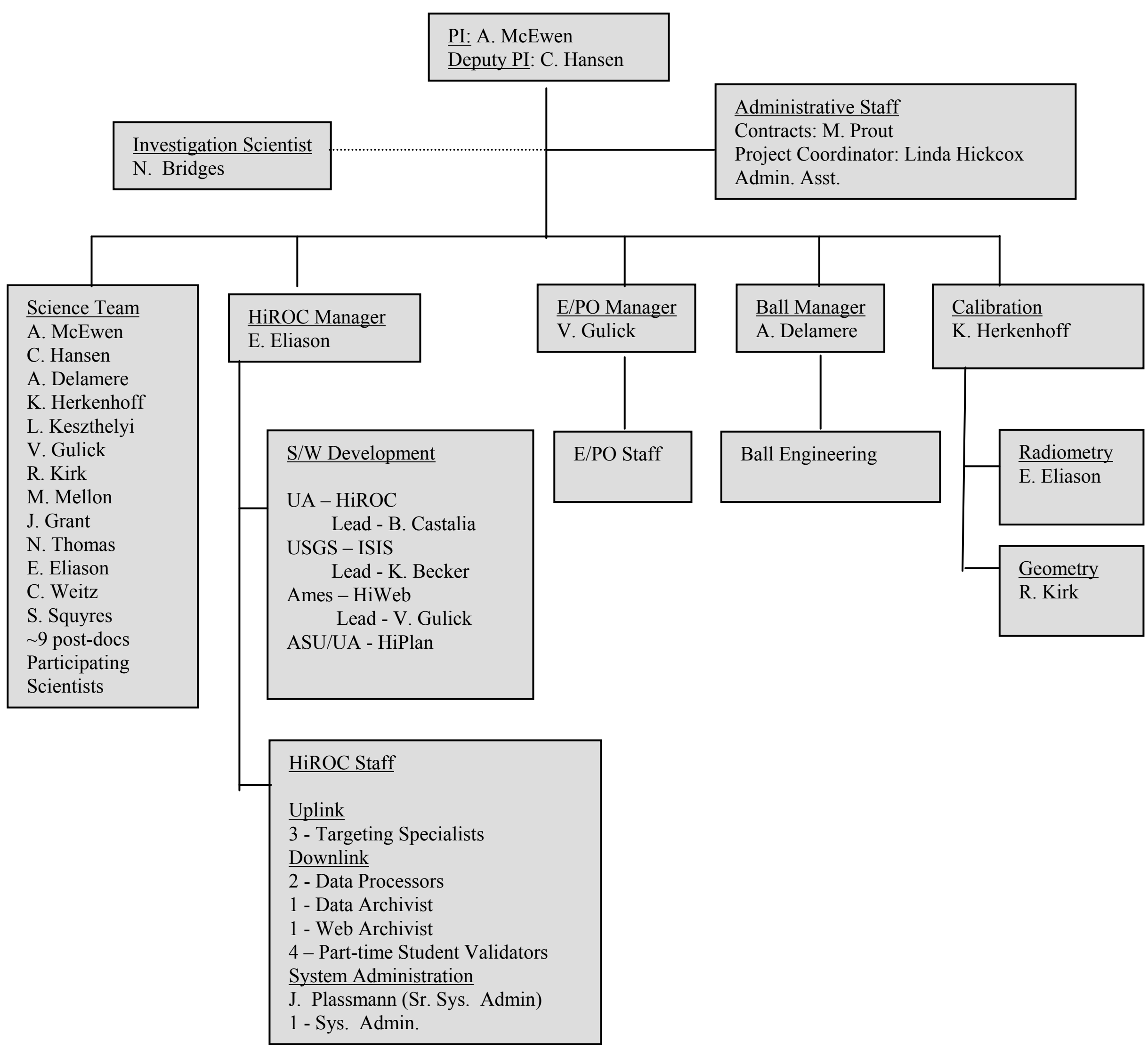

Figure 2.1. - HiRISE Phase-E organizational chart.

Table 2.1a - Science Support

	FY04	FY05	FY06	FY07	FY08	FY09	Tot
U/A Science and Administrative Staff							
Alfred McEwen (PI) (6 months paid; 2 months contributed)	0.50	0.50	0.50	0.50	0.50	0.33	2.83
Post-Doctoral Researcher # 1			1.00	1.00	1.00	0.66	3.66
Post-Doctoral Researcher # 2 (half-time)			0.50	0.50	0.50	0.33	1.83
Graduate Student # 1			1.00	1.00	1.00	0.66	3.66
Graduate Student # 2			1.00	1.00	1.00	0.66	3.66
Contracts Negotiator	0.30	0.30	0.30	0.30	0.30	0.20	1.70
Program Coordinator			1.00	1.00	1.00	0.66	3.66
Admin. Assistant			0.50	0.50	0.50	0.33	1.83
CO-I Science and Science Support Staff							
JPL							
Candice Hansen (Deputy PI)	0.30	0.30	0.40	0.50	0.50	0.33	2.33
Ball Aerospace							
Alan Delamere (Co-I and Project manager)	0.75	0.75	0.50	0.25	0.25	0.25	2.75
Ball Aerospace Engineering Support	-	-	TBD	TBD	TBD	TBD	0.00
USGS							
Ken Herkenhoff (Co-I)	0.15	0.08	0.40	0.50	0.50	0.33	1.96
Randolf Kirk (Co-I)	0.08	0.11	0.33	0.33	0.33	0.20	1.38
Laszlo Keszthelyi (Co-I)	0.20	0.20	0.50	0.50	0.50	0.33	2.23
USGS Post-Doctoral Researchers			1.50	1.50	1.50	0.66	5.16
DEM Production/ Processing Staff / Calibration Support			0.35	1.47	1.47	0.87	4.16
AMES							
V. Gulick (Co-I & EPO Manager)	0.20	0.25	0.63	0.68	0.60	0.38	2.74
SETI Post-Doctoral Researcher			0.50	1.00	1.00	0.67	3.17
E/PO Coordinator	0.15	0.15	0.40	0.40	0.40	0.20	1.70
E/PO Web Development	0.05	0.10	0.25	0.25	0.25	0.10	1.00
E/PO "clicworkers" module			0.20	0.20	0.20	0.00	0.60
Smithsonian CEPS							
John Grant (Co-I contributed costs)	0.20	0.10	0.40	0.50	0.50	0.33	2.03
CEPS Post-Doctral Researcher			1.00	1.00	1.00		3.00
Cornell							
Steven Squyres (Co-I)	0.04	0.08	0.17	0.17	0.17	0.17	0.79
Cornell Graduate Assistant			1.00	1.00	1.00	1.00	4.00
Post-Doctoral Researcher		0.08	0.25	0.25	0.25	0.25	1.08
University of Colorado							
Mike Mellon (Co-I)	0.17	0.21	0.42	0.50	0.50	0.42	2.22
UC Post-Doctoral Researcher			0.58	0.50	0.50	0.42	2.00
Planetary Science Institute							
Catherine Weitz (Co-I)	0.20	0.20	0.50	0.50	0.50	0.20	2.10
PSI Reseach Assistant			0.50	1.00	1.00	0.50	3.00
University of Bern							
Nick Thomas (Co-I) Contributed Costs	0.20	0.20	0.50	0.50	0.50	0.20	2.10

Table 2.1b - HiROC Development and Operations Staffing							
	FY04	FY05	FY06	FY07	FY08	FY09	Tot
U/A Operations Staffing							
HiROC Manager - Eric Eliason	0.60	1.00	1.00	1.00	1.00	0.66	5.26
HiROC Senior System Administrator (contibuted FY04-05)	0.20	0.20	1.00	1.00	1.00	0.50	3.90
HiROC Systems Administrator			1.00	1.00	1.00	0.30	3.30
Uplink							
Targeting Specialist #1 (lead)			1.00	1.00	1.00	0.50	3.50
Targeting Specialist #2			0.39	1.00	1.00	0.30	2.69
Targeting Specialist #2			0.19	1.00	1.00	0.30	2.49
Downlink							
Data Processing Specialist # 1			1.00	1.00	1.00	0.50	3.50
Data Processing Specialist # 2			0.19	1.00	1.00	0.50	2.69
Data Archive Specialist			1.00	1.00	1.00	0.50	3.50
Web Archive Specialist			1.00	1.00	1.00	0.50	3.50
UA Student Validators (at 1/2 time employment)			1.00	2.00	2.00	1.00	6.00
Totals for HiROC Operations:	0.80	1.20	8.77	12.00	12.00	5.56	40.33
Software Development Staffing							
Totals for UA Development	2.50	2.50	7.00	5.08	2.32	0.81	20.21
Totals for AMES Development	0.33	0.50	0.76	0.38	0.30	0.00	2.27
Totals for USGS Development	1.00	1.00	3.34	3.51	0.54	0.50	9.89
Totals for HiROC Software Development:	**3.83**	**4.00**	**11.10**	**8.97**	**3.16**	**1.31**	**32.36**

2.2 Science Team

The HiRISE science team is an integral part of HiRISE operations. Each Co-I will be responsible for a particular science theme and/or objective. That responsibility includes prioritization of suggested images received from scientists external to the project, participation in observation planning ensuring theme scientific goals are achieved, a monthly rotation in sequence development, validation of data received, and leadership in papers, workshops, and presentations centered on their theme. Science themes identified for Co-Is are: (1) landscape evolution, including eolian, cratering, and mass-wasting processes (Grant); (2) fluvial and hydrothermal processes (Gulick); (3) seasonal processes (Hansen); (4) volcanism (Keszthelyi); (5) polar geology (Herkenhoff); (6) glacial/periglacial and regolith processes (Mellon); (7) future exploration (Squyres); and (8) layering processes and stratigraphy (Weitz). Themes and other responsibilities of Science Team members are summarized in **table 2.2.**

An important function will be the "Co-I of the Month", whose duties will be to lead the science prioritizations for a month of operations. We anticipate that ~6 Co-Is will participate, each handling ~2 months per year. His/her work for a month of observation will actually extend over 2+ months. Prior to the observation period, he/she must coordinate target prioritizations among the science team. During the month, he/she works closely with the targeting specialists, SOWG, TAG, other MRO experiments, and the Co-Is to make/coordinate science decisions. After the observation month, he/she is responsible for scientific validation of the images collected during his/her shift, to verify if the science objectives were achieved. He/she will also coordinate the production of captioned image releases (5/week) from images acquired over the observation month. The Co-I/Month will solicit help from other team members as appropriate.

The PI plans to withhold a portion of Co-I funding for this Co-I/Month function, releasing that funding only to those Co-Is who actually make the committment.

Table 2.2 - Science Team Roles and Responsibilities

Team Member	Role / Responsibility / Science Theme	Institution
Alfred McEwen	Principal Investigator / Coordinates Science Theme Objectives	LPL, University of Arizona
Candice Hansen	Deputy PI / Uplink Design / Polar Landing Sites / Seasonal Processes	JPL
Alan Delamere	HiEST lead in Phase-E	Ball Aerospace
Eric Eliason	Manager of HiROC / Downlink Design	LPL
Virginia Gulick	E/PO Lead / Fluvial and hydrothermal processes / HiWeb lead	NASA Ames/SETI Institute
Ken Herkenhoff	Calibration Lead / Polar geology	USGS
Nick Thomas	European Operations / Spectrophotometry	Bern
Randolph Kirk	Geodesy and DEM production / Geometric calibration lead	USGS
John Grant	Landscape evolution, eolian, cratering, and mass wasting processes / MSL landing sites	Smithsonian Institution
Laszlo Keszthelyi	Observation planning process / Volcanism	USGS
Mike Mellon	Periglacial, Glacial, and Regolith Processes	University of Colorado
Steve Squyres	Future Exploration / MER landing sites	Cornell University
Cathy Weitz	Layering Processes and Stratigraphy	Planetary Science Institute

Principal Investigator, Alfred McEwen

Alfred McEwen leads HiRISE and is responsible for the successful implementation of the investigation. He provides the scientific leadership for the HiRISE team investigators and leads team interaction with the MRO Project Science Group (PSG), Target Acquisition Group (TAG) and the wider Mars planetary community. Alfred will provide guidance and leadership to the technical support team and ensure that science objectives are met. He will organize team meetings about 3 times per year. He will coordinate the dissemination of HiRISE results at scientific conferences and in publications.

Deputy Principal Investigator, Candice Hansen
Candice Hansen is the HiRISE Deputy PI (DPI). Her primary responsibility includes defining software requirements for the instrument, defining uplink processes for HiRISE, developing command sequences for tests and ATLO (Assembly, Test, and Launch Operations), and planning HiRISE team test and training. She will also be the day-to-day interface to the JPL MRO Science Office and Mission Management Office (MMO). She has the authority to act for the PI and represent HiRISE whenever necessary. Both the PI and DPI will attend PSG and TAG meetings.

Instrument Manager, Alan Delamere
Alan Delamere is responsible for leading the instrument design at Ball Aerospace. During Phase-E he will be the primary contact with the Ball engineering staff for HiRISE instrument engineering support.

Manager of HiROC, Eric Eliason
Eric Eliason is the HiROC manager with the primary responsibility for overseeing operations, staff, and scheduling. He oversees the software development efforts for sequence planning, S/C commanding, catalog and database management, image processing, and data validation and archival. He will represent the HiRISE team at MRO Data Archive and Working Group (DARWG) meetings. He will retire from USGS in April 2004 and become a full-time employee of LPL, but will retain an emeritus position at USGS and continue to ensure progress in USGS ISIS software development for HiRISE. He will also lead the radiometric calibration data reduction (ground and flight data).

E/PO Manager, Virginia Gulick
Virginia Gulick is the HiRISE Education and Public Outreach (E/PO) manager responsible for planning, executing, and arranging for evaluation of E/PO activities. She works with the other HiRISE Co-Is responsible for local E/PO activities and the HiRISE Educational Advisory Council (EAC) to ensure an overall quality effort. She supervises development of the interactive website for HiRISE (HiWeb).

Calibration Lead, Ken Herkenhoff
Ken Herkenhoff leads the pre-flight and in-flight calibration for the HiRISE camera and coordinating the efforts of other Co-Is in the calibration effort.

Other team members contribute as summarized in **table 2.2.** Many team members in addition to those listed above will be interested in landing site studies.

2.3 Project Administration

Project administration functions are carried out at the UA under the direction of the PI and HiROC Manager. During Phase-E a Project Contracts Manager (Mike Prout) will be carried at one-third time. A full-time Program Coordinator/Budget Analyst (Linda Hickcox) and an Administrative Assistant will carry out the essential day-to-day administrative functions of procurement, accounting, personnel administration, travel, and other tasks.

2.4 Mission Operations

Candice Hansen and Eric Eliason are responsible for concepts and definition of requirements for uplink and downlink, respectively. The HiRISE team sub-group HiSYS, lead by Eric Eliason, is responsible for defining the requirements, system design, hardware architecture, and vision for HiROC. HiSYS members include Eric Eliason, Candice Hansen, Alfred McEwen, Laszlo Keszthelyi, Virginia Gulick, Joe Plassmann, Nathan Bridges, Ira Becker (Ball), Bradford Castalia, and other science team members as needed.

The HiROC staffing for operations and system software development, summarized by fiscal year (FY), are shown in **table 2.1b**. The levels reflect total staffing requirements for uplink and downlink processes, HiROC and science analysis software development, and data archiving and delivery of data products to the archiving institution. The specific duties of the staff members are elaborated in **section 6**.

For general uplink activities we plan to hire 3 FTE (Full Time Equivalent) Targeting Specialists who will lead the day-to-day instrument targeting and command load generation. We may hire post-docs who are ~1/2 time targeting specialists and 1/2 time researchers, but there will be the equivalent of 3 FTE for targeting and working with the Co-I of the month.

2.5 Science Data Processing

Science Data processing work is carried out at the HiROC facility and the Co-I institutions. HiROC will have two full-time Data Processing Specialists responsible for generation of the HiRISE standard data products. Co-Is will be provided with workstations and the ISIS processing system to support their research activities and special processing requirements. The production of DEMs will be carried out at the USGS under the direction of Co-I Randolph Kirk.

2.6 Data Archive and Distribution

Two full-time HiROC staff members, a Data Archive Specialist and a Web Archive Specialist, are designated to carry out the data archiving activities described in **section 6**. Eric Eliason will participate in the MRO Data Archive Working Group (DARWG) to define overall data transfer and validation procedures. The four downlink staff members (two data processing, data archive, and web specialists) will be cross-trained to provide coverage during vacations or other absences.

2.7 Software Development and Maintenance

The HiROC manager will oversee the HiRISE software development and maintenance. The software development staffing, by institution, is shown in **table 2.1b**. (Note that the 7.0 FTE at UA in FY06 may be reduced via a contract with MTT development group at ASU to assist with HiPlan.) Development of the HiROC facility and supporting data analysis tools will result from a coordinated development effort among PI and Co-I institutions at the UA, USGS, and Ames, as well as coordination with software developers at JPL, Ball, LMA, SEAKR, and ASU. The software development plan is described in **section 9.** The HiTECH group has been formed and is holding weekly meetings to facilitate development of the HiROC ground data system.

2.8 Science Analysis and Validation

Science Analysis supported via this EOP is carried out by the PI, Co-Is, post-docs, and students at their home institutions. This team science analysis is essential to MOS, to ensure that we collect data that is optimized for high-priority science objectives. During Phase-E, most Co-Is (Hansen, Gulick, Herkenhoff, Keszthelyi, Mellon, Weitz) are funded at approximately 1/4 time for science analysis and another 1/4 time is available for Co-I/month activity. Co-Is Grant, Squyres, and Thomas are largely contributing their salaries, which will include science analysis (and perhaps Co-I/month). Co-Is Delamere, Eliason, and Kirk have specialized roles, contributing to engineering support, data analysis and validation. A full-time post-doctorate or research assistant supports most Co-Is. The PI and Co-Is Squyres and Thomas will support students. The Co-Is, post-docs, and students will contribute to producing 5 captioned image releases per week in addition to targeting and data analysis.

The scientific validation of HiRISE data products is accomplished through science analysis by the science team and the instrument calibration activity. The data archiving staff is responsible for the technical validation of the data products ensuring data products meet PDS standards. A staff of part-time undergraduate and High School students will be hired to provide quick-look validation of all Level-0 and Level-1C (processed) products. They will quickly scroll over all products, flagging any anomalies and filling out a web-based worksheet for each image. If time permits, they will collect information about surface features in the images (presence of gullies, layers, patterned ground, etc.) for the searchable database.

2.9 Education and Public Outreach (E/PO)

Virginia Gulick will be the HiRISE E/PO manager. She will be responsible for planning, executing and arranging for evaluation of E/PO activities. She will work with the other HiRISE Co-I's responsible for local E/PO activities and the HiRISE Educational Advisory Council (EAC) to ensure an overall quality effort. See E/PO plan for further details.

2.10 Investigation Scientist

Nathan Bridges is the HiRISE Investigation Scientist (IS) at JPL. Overall, his responsibility is to serve as an interface between the MRO project and the HiRISE investigation. This entails being aware of spacecraft, ground system, data system, and HiRISE requirements in order to assure that the investigation successfully operates per its objectives on MRO. He will also continue to coordinate in-flight calibration observation activities.

During Phase-E, he will participate in HiRISE mission operations to ensure a good understanding of HiRISE needs for coordination with the project and other science teams. In addition to these tasks, the IS may be asked to perform other necessary duties that, due to his convenient location at JPL and time constraints of other personnel, cannot be performed by the HiRISE science team. As a geologist and planetary scientist he will assist the science team in data analysis tasks as needed.

2.11 Participating Scientists and Guest Observers

The HiRISE team would welcome participating scientists with expertise in geology, atmospheric science, cartography, remote sensing, and other related disciplines. Proposers should show how the use of MRO experiments (HiRISE in particular) would benefit the investigation of well-defined scientific problems. They should have a good understanding of the instrument. Once selected, these individuals will be full members of the HiRISE science team and will participate in data analysis, E/PO activities, and mission operations. Proposers should demonstrate a need for their presence during mission operations (investigators focused solely on data analysis are judged more suitable for NASA Research and Development programs). We also encourage NASA to support a Guest Observer program.

2.12 Instrument Calibration

Ken Herkenhoff will lead the overall pre-flight and in-flight calibration investigations of the HiRISE camera, as described in the HiRISE Calibration Plan. He will update the Calibration Plan and be responsible for the production of the Calibration Report. Alan Delamere and Dino Rosetti and/or Jim Bergstrom of Ball will organize the ground calibration setup (see HiRISE Integration and Testing plan). Eric Eliason will lead the radiometric calibration data reduction effort and Randy Kirk will lead the geometric calibration effort. Alfred McEwen will orchestrate the ground calibration efforts by Science Co-Is at Ball during early 2004 when Herkenhoff will be occupied by Mars Exploration Rover activities. If ground calibration slips to June or July 2004, McEwen will be distracted by Cassini activities, but Herkenhoff should be available.

3 PROJECT INTERFACE

The MRO project has a distributed architecture for Phase-E. The science instrument teams will operate their instruments from remote sites. The HiRISE Operations Center (HiROC) will be located at the PI's institution, the Lunar and Planetary Lab at the University of Arizona, Tucson. All instrument commands will be developed at HiROC. The project will furnish a secure line, a Science Operations and Planning Computer (SOPC) and software for transfer of instrument commands to JPL for radiation to the spacecraft. Likewise data will be pulled from JPL to HiROC for all data processing.

The HiRISE/MRO Project interface is shown in **table 3.0**. The interface function, point-of-contact for the HiRISE team, and the MRO project are listed.

Table 3.0 - Phase-E Project Interface

Interface	HiRISE Contact	Project Contact
PSG (Project Science Group)	A. McEwen / C. Hansen	R. Zurek / S. Smrekar
Instrument Payload	E. Eliason	B. Jai / C. Kloss
TAG (Target Acquisition Group)	A. McEwen / C. Hansen	R. Zurek / S. Smrekar
POST (Payload Operations Support Team)	Targeting Specialist	B. Jai / D. Wenkert
SOWG (Science Operations Working Group)	N. Bridges	B. Jai
Mission Management Office	C. Hansen	C. Hansen
MRO/GDS - Uplink Data Flow	C. Hansen	D. Wenkert
MRO/GDS - Downlink Data Flow	E. Eliason	S. Noland
DARWG (Data Archive Working Group)	E. Eliason	R. Arvidson
E/PO (Education and Public Outreach)	V. Gulick	M. Viotti

4 REQUIREMENTS FOR GOVERNMENT-FURNISHED SUPPORT

The HiRISE requirements for support from the MRO project is summarized in **table 4.0.**

Table 4.0 - MRO Project Furnished Support ro HiRISE

Item	Description
SOPC	The project shall provide to the HiROC facility a fully functioning Science Operations and Planning Computer (SOPC) for interface with the MRO GDS.
SOPC Backup	In the event of loss of the HiROC SOPC, the project will make available a backup SOPC system located at JPL.
SOPC Training	The project shall provide training to HiROC staff in the operations and use of the SOPC facility.
SOPC Maintenance	The project shall provide maintenance and support to the SOPC.
Telecommunications	The project shall provide a secure dedicated communications line between HiROC and MRO GDS. The bandwidth shall be equivalent to two T-1 lines.

SPICE	The project shall provide both predict and reconstructed SPICE kernels to the HiRISE team. The essential SPICE kernels include the SPK and CK kernels.
Engineering Data	The project shall provide access to the HiRISE engineering data steam (that has been decommutated and channelized on the ground) to support HiRISE instrument health monitoring.
Multi-mission uplink, query tools, and other software with training	The project shall provide uplink tools to the HiRISE team for coordinating uplink processes. Query tools will be provided to determine the status of uplink and downlink data flows. Software tools will include SEQGEN, APGEN, SEQTRAN, DMD, FEI, MTT, Data Tracker, and other multi-mission tools. The project shall provide training for all authorized users of these tools.
Data transfer to HiROC	The project shall provide data processing tools to remotely access and download HiRISE instrument data in CFDP form for delivery to the HiROC data base system.

5 PROJECT ADMINISTRATION PLAN

HiRISE project administration is carried out at the UA under the direction of the PI. The administrative staff is made up of part-time Contracts Manager Mike Prout, a full-time Program Coordinator Linda Hickcox, and a full time administrative assistant. The Contracts Manager will (1) work directly with the JPL and UA contracting offices, (2) attend meetings at JPL to coordinate contract activities, and (3) work with sub-contractor institutions to coordinate funding transfer to the Co-I institutions. The university overhead for contract coordination is 51.5% for the first $25K of sub-contractor funding with no additional overhead after $25K. Because Ames is a NASA research center, sub-contract funding to Co-I Virginia Gulick is transferred directly from JPL to Ames with no UA overhead incurred; there is likewise no overhead for funding of Candice Hansen at JPL. Equipment purchases are burdened at 51.5% for the first $5k of equipment procurement.

The Program Coordinator, supported by an Administrative Assistant, will (1) make travel arrangements for the HiRISE team at the UA, (2) make meeting arrangements as necessary, (3) perform budget analysis, (4) secure purchase orders, (5) act as primary contact for visitors, (6) carry out hiring procedures for new staff, (7) support written and telephone correspondence, (8) perform record keeping duties such as equipment logging, (9) monitor contracting issues, and (10) support facility development. This work is often time-critical so we cannot have just one Program Coordinator, so the assistant can cover for the Coordinator during vacations and sick leave and help with the large workload.

6 MISSION OPERATIONS

The goal of mission operations is to successfully carry out the HiRISE science investigation. This means building and operating a science operations center that emphasizes involvement in all aspects of camera operation. In the following sections we will describe science planning, the design of HiROC, uplink processes, scenarios for instrument operation, downlink processes, how we will monitor instrument health, and how we will prepare for mission operations.

HiRISE operations will be concentrated at the HiRISE Operation Center (HiROC) on the University of Arizona campus, with some mission support activities occurring at Co-I and Participating Scientist

Institutions: Ball Aerospace will lead the monitoring of camera health and engineering (described in **section 6.5**); JPL is the center for MRO mission operations; NASA Ames/SETI Institute (Co-I Gulick) will be the center for E/PO activities and the development of HiWeb; USGS will be the home for ISIS software development and maintenance and production of Digital Elevation Models (DEMs); and data analysis will be carried out at all Co-I institutions.

Key milestones in the mission which drive the HiROC development and HiRISE team plans for operation are:

- ATLO (begins August, 2004)
- Launch (August 2005) and subsequent cruise calibrations
- Mars Orbit Insertion (March 2006)
- Transition Phase (begins ~ September 2006)
- Primary Science Phase (November 2006).

HiRISE mission operations during PSP will typically operate on an 8 hour/day 7 day a week schedule. The schedule may vary during high activity periods that warrant more flexible operations. Enough opeations staff exist to ensure seven day a week coverage. We plan to have individuals on 24 hour call in order to respond situations that need immediate attention such as when the HiRISE instrument exceeds operational limits. These individuals will be trained to assess the danger to the HiRISE instrument and take appropriate acction as necessary. A paging system will be implemented (coordindated with operations at JPL) that will automaticly alert the individual on call.

6.1 Science Planning

The planning of science data acquisition by the MRO project will be a multi-stage process and will involve a broad swath of the Mars science community. Special emphasis will be given to examination of potential landing sites for future Mars missions. The HiRISE science planning process can be divided into 2 main activities. The first involves selecting locations on Mars that should be imaged by HiRISE and is independent of time. The second is a time-dependent process and involves creating orbit-by-orbit sequences to acquire specific images.

Suggestions for locations on Mars to image (with a detailed science rationale) can be input into the HiCat database via the HiWeb interface at any time. The HiRISE team will hold workshops in conjunction with major scientific meetings in order to foster input from the planetary community. By combining these workshops with opportunities to share the latest science results from HiRISE, we hope to maximize the community's understanding of the capabilities and limitations of HiRISE. This should assist in ensuring that the suggestions are of a high quality, both at the workshop and later via the web. The web process is described in some detail in **section 6.3.1**, but will involve input from the general public, the Mars science community, the Target Acquisition Group (TAG), and the HiRISE team.

Each HiRISE Co-I is assigned a science theme to monitor during the planning process (see **table 2.2**). Target suggestions will be categorized by theme, and prioritized by the Co-I in charge of a given science theme. The orbit-by-orbit planning will be completed in 28-day cycles that are described in more detail in **section 6.3.2**. A single Co-I will follow a 28 day sequence through its planning, implementation and execution life cycle, altogether two months long. This Co-I will be responsible for after-the-fact assessment of whether the science goals of the images in the sequence were achieved. This responsibility will rotate, with two Co-I's overlapping at any given time.

6.2 HiRISE Ground Operation Center

6.2.1 HiROC Ground System Design Summary

A HiROC Peer Review was held in January 2003 prior to the MRO MOS/GDS PDR, and a HiROC peer review prior to CDR will be held in November 2003. The HiROC architecture and complete uplink and downlink data flow is illustrated in **figure 6.2.1.**

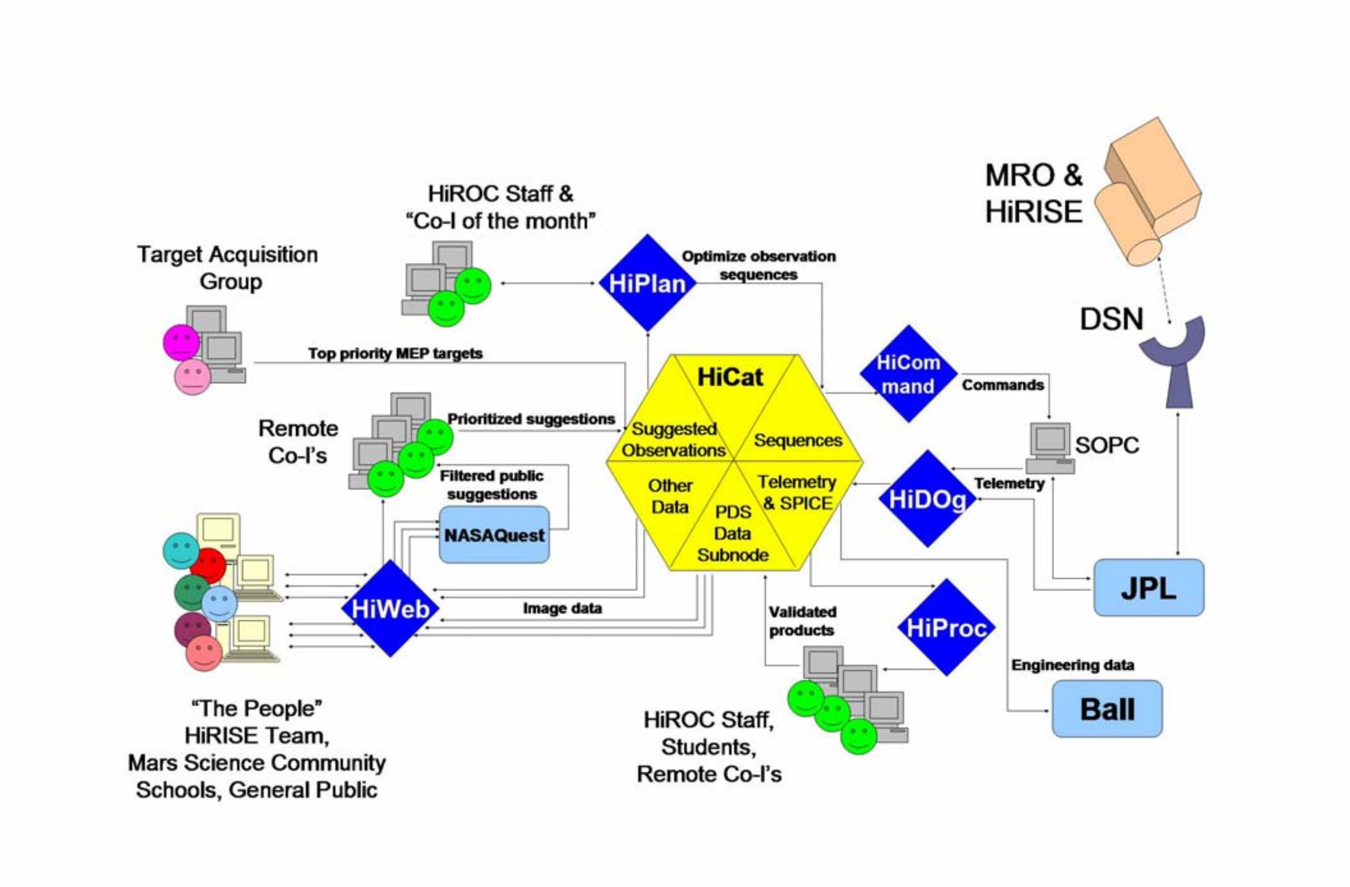

Figure 6.2.1 - HiRISE Ground Data System, designed to optimize Mars Science, while giving high-priority to exploration and E/PO. Images can be suggested and viewed by anyone via a user-friendly web interface (HiWeb). Suggestions from the project-level TAG will go directly to HiCat, whereas others will be prioritized by the Co-Is. The distributed Co-Is will assist the HiROC staff in planning the actual observation sequences with HiPlan, and instrument commands will be sent to the secure SOPC. Images returned from the spacecraft will be retrieved by HiDOG from JPL and inserted into HiCat through a dedicated line to the RSDS. The images are processed by the HiProc procedures and checked by HiROC staff, students, and others to verify processing results. The processed and validated images should be available to all within weeks of acquisition.

HiROC will be put in place incrementally, starting during ground calibration to support data collection and analysis. The basic software and hardware to support uplink of HiRISE commands and downlink of HiRISE data from the project will be put in place in Phase C/D to support ATLO and ORTs. In Phase-E, HiROC will be the hub of the distributed HiRISE science planning and data analysis.

Central to the HiROC data system is the HiRISE Catalog and Database Management System (HiCat) containing critical information such as HiRISE data, ancillary data, data from other Mars missions, image suggestions, and information about system events that occur on the spacecraft, instrument, and within HiROC. HiCat tracks events associated with both uplink and downlink dataflow via a unique image ID that follows the image from the Earth to the spacecraft and back. HiCat enables automated operation of routine data retrieval and processing. The automated procedures can interrogate HiCat to determine when processing can occur and provide logs of all their activities. Operations personnel can obtain data processing status reports by accessing the event catalogs. A summary of the databases maintained by HiCat are shown in **table 6.2.1.**

Table 6.2.1 - HiCat Tables	
Activity log	Catalog of HiROC uplink and downlink dataflow and processing events.
People	Catalog of people involved in all aspects of HiRISE operations, providing a mechanism to limit access to only the appropriate sections of HiCat.
Suggested Images	Catalog of suggested locations to image. Includes information such as geographic position, minimum image area, desired viewing geometry, need for color and/or stereo, seasonal constraints, and science rationale. The requestor is automatically tracked and priority levels are input by Co-I's.
Planned Observations	Catalog of all planned, pending, acquired, and failed observations. Lists all camera operating parameters planned for each observation.
Sequences	Catalog of observation sequences and PTFs. Tracks all commands sent to HiRISE
Acquired Images	Catalog of HiRISE raw and processed images. Includes all the information in the image headers and tracks the image through the processing steps. Allows HiRISE image collection to be searched by a variety of criteria including geographic location, target name, time, and camera state.
Ancillary Data	Telemetry and ancillary data.
Other Data	Image data and catalog of other mission datasets (CRISM, MOC, MARCI, CTX, THEMIS, MOLA, TES, Viking, and perhaps Mars Express data) that support HiRISE targeting and data analysis.

Footnote: Full list of table entries described in HiCat FRD.

The remaining HiROC software, hardware, and personnel can be conceptually divided into groups supporting the uplink and downlink processes, as described in the following sections.

6.3 Uplink Processes

6.3.1 Gathering Image Suggestions

The suggestions of locations on Mars that HiRISE should image are considered a time independent process that can occur weeks, months, or years before the target is observed. Development of observation sequences begins by interrogating the suggested image database for potential observations. A web-based facility, HiWeb, will assist users in formulating and submitting image suggestions. HiWeb, modeled after Marsoweb (http://marsoweb.nas.nasa.gov/landingsites), will be developed at NASA Ames/ SETI Institute. Marsoweb provides a suite of tools that is used to analyze landing sites for Mars Exploration Rovers (MER) Landing Site Selection process (See **Appendix H** for current Marsoweb capabilities). HiWeb users will have the capability to browse existing images and other datasets from past, current and upcoming Mars missions including Viking, MGS, Odyssey, Mars Express, and MRO. In addition, HiWeb will serve relevant derived data products of interest for landing site selection and other studies (e.g., thermal inertia and surface roughness data and maps). The latest USGS Mars Digital Image Maps

(MDIM's), and maps produced from TES, MOLA, THEMIS, GRS, and MGS magnetometer data as well as available data from Mars Express will be accessible from HiWeb's interactive data map simply by selecting the appropriate radio button(s). Users will be able to compare and overlay these data sets and pan and zoom on the data map to desired regions of interest.

After browsing desired datasets, HiWeb users registered for targeting will specify a suggested image along with acceptable image parameters such as image size, minimum resolution, emission, incidence, phase angles, seasonal observation period and other constraints. To complete an image suggestion, users will be asked to add a brief, well-motivated science justification for use of HiRISE to image the region of interest. Once the suggestion is submitted, an automated email response will be sent confirming receipt of the suggestion. If the suggested image is acquired, it will be automatically posted to the HiWeb site. The requestor can check the website to see what images have been acquired for or near their region of interest. The HiRISE team plans to make HiWeb's image suggestion system available around the time of launch and to continue the effort throughout the duration of the mission.

There are three classes of requestors: HiRISE team members, the TAG, and the general public. The HiRISE team access will be password protected allowing Co-Is to prioritize image targets from the science community and public and add text comments. The TAG suggestions will be tagged with the requesting scientist's identification and routed to the Co-I of the month to receive the highest priority. Other image suggestions will come from K-14 students involved in E/PO activities supervised by a HiRISE team member. These images will be treated the same as if they came directly from the team member.

The general public and unsupervised K-14 students will also use HiWeb to identify potential observations. In our baseline user scenario (see **Appendix I** for additional HiWeb material), student and public suggestions will be routed to an E/PO partner (presently NASA Quest) in FY06 through FY08 for selection and approval. Students and the general public would be able to participate in web chats, web casts, and forums involving HiRISE team members in order to help guide and educate the public about Mars and the image suggestion process. The E/PO partner will advertise to schools, and sponsor and provide the necessary communications support for the web events. The E/PO partner will also conduct web polls to determine the most popular candidate sites with the highest scientific value. The polling process will help reduce the suggestions to a manageable number should the number of suggestions from the public become an issue.

In our desired user scenario, an automated image-suggestion and filtering system will also be available on HiWeb to accept user suggestions directly into the HiRISE image suggestion catalog. The user experience will be similar to that described above, except image suggestions will be taken throughout the mission and would not necessarily be filtered first by an E/PO partner.

Regardless of which scenario we ultimately decide to implement, our goal is to acquire at least one E/PO selected target per week. E/PO image suggestions will be highlighted, with the requestor(s), on the HiRISE web page. This image suggestion process need not require a large data volume nor require a lot of time, as it would be provided on a best effort basis by the team.

A minimal working HiWeb system will be in place by launch so that during the cruise phase, the science team, science community, and the public can populate HiCat's catalog of image suggestions. The baseline version of HiWeb will be on line by Mars orbit insertion. HiWeb will continue to be updated as the mission progresses.

6.3.2 Observation Sequence Planning

The project will command the MRO spacecraft via 28-day background sequences. These sequences control the communication of the spacecraft with the earth. The DSN coverage will be firm at the start of the planning cycle for a background sequence 4 to 7 weeks before execution. The PSG will decide on data volume allocations for the SSR in accord with data return capabilities and science goals. The allocation of SSR space and downlink data return will be a boundary condition to our observation planning. **Table 6.3.2** summarizes the HiRISE tasks that occur during the TAG sequence planning process.

Observations may be acquired as non-interactive (usually nadir-pointed) or interactive (with the spacecraft turned off-nadir). The spacecraft may be turned up to 30 degrees off-nadir to ensure imaging of high priority targets and for optimal stereo geometry. Even allowing for navigation uncertainties this capability allows imaging of the target to be scheduled weeks in advance of sequence execution. "Interactive Observations" (IO) require coordination with other instrument teams. The Project will run a sequence planning cycle for each 28-day sequence to integrate the IO timeline. The HiRISE science team will meet via a monthly telecon to decide on our top priority targets for that 28-day cycle. The HiRISE team is responsible for delivering Pointing/Target files (PTFs) per the project schedule with our desired targets. The Co-I-of-the-Month works with a Targeting Specialist to run HiPlan to identify all opportunities to image a given target and work out a strawman HiRISE timeline. After conflicts have been resolved at the project level an Integrated Target List (ITL) with the IO's is uplinked to the spacecraft. The spacecraft will autonomously update the turn block by means of onboard ephemeris updates such that both timing and off-nadir angles are updated with the best available spacecraft trajectory knowledge at the time of execution.

Non-interactive (nadir) observations will be opportunistic in nature. These observations by definition do not turn the spacecraft off-nadir, thus generally do not require special coordination with other instrument teams. (In practice the potential for ride-along science means that we will communicate plans with our counterparts on CRISM and CTX.) A non-interactive observation during off-nadir slews is also possible. The interface to the spacecraft will be via the Integrated Target List (ITL) and will use a similar spacecraft block structure as that for off-nadir turns to enable timing updates for observing a specific latitude. HiRISE non-interactive imaging will be planned on a weekly basis by the Co-I-of-the-Month and a Targeting Specialist.

The HiRISE team also expects that the HiRISE, CRISM, and CTX teams will share their sequence plans so that each team will be aware of the other's plans. This will facilitate both coordinated and "ride-along" observations where CRISM, HiRISE, or CTX collect some data when the other instrument is acquiring observations. These ride-along observations will not involve careful coordination and either team should be able to make changes to its non-interactive observations at any time without consulting the other team.

Table 6.3.2 – 28-Day TAG Monthly Sequence Planning Process	
Week 0	• HiRISE teleconference: Identify and prioritize targets for Sequence N (all Co-Is participate) • Targeting Specialist (TS) runs HiPlan to identify all viable times for imaging a given target.
Week 1	• Project Sequence Kickoff Teleconference – Approximate DSN coverage and data volumes become known.

	• HiRISE, CRISM, CTX propose coordinated observations and communicate desires to each other. • Teams decide which observations require coordination (increases priority of target) • Friday: Project Science Kickoff Teleconference – DSN coverage finalized, downlink data volume can be calculated precisely.
Week 2	• Monday: Deliver PTF-1 to project with all observations prioritized and acceptable alternative times identified for each target. • Interactive Observation integration (process to be decided by PSG) • Data Tracker tool run to manage HiRISE SSR resources.
Week 3	• Monday: TAG teleconference to resolve any remaining conflicts, set guidelines for Sequence N+1 • Non-interactive nadir observations for week 4 are integrated into PTF; PTF is delivered • Review of project IPTF and ITL • HiRISE image sequences (camera configuration) for week 4 generated, transferred to JPL and radiated to spacecraft •
Sequence Execution Begins:	
Week 4	• Sequence N is radiated to spacecraft and begins execution • Non-interactive nadir observations for week 5 are integrated into PTF • HiRISE image sequences (camera configuration) for week 5 generated, transferred to JPL and radiated to spacecraft.
Week 5	• Sequence N execution • Non-interactive nadir observations for week 6 are integrated into PTF • HiRISE image sequences (camera configuration) for week 6 generated, transferred to JPL and radiated to spacecraft
Week 6	• Sequence N is executed • Non-interactive nadir observations for week 7 are integrated into PTF • HiRISE image sequences (camera configuration) for week 7 generated, transferred to JPL and radiated to spacecraft
Week 7	• Sequence N execution
(This is the two-month period of time the Co-I-of-the-month covers. As the sequence executes the Co-I reviews the images downlinked in addition to developing the nadir observation plan.)	

6.3.3 Observation Scenarios

HiRISE differs from other MRO instruments in that it does not have plans for any systematic global observations. Instead, the observation strategy is to continually fill the downlink stream with local observations. Thus the HiRISE imaging plans are driven by trade-offs between key limited resources such as (1) what is visible on the surface, (2) space on the SSR, (3) available downlink, (4) and timeline constraints. As a result we expect the daily activities of HiRISE to be extremely variable. In order to describe some of this variability, we discuss a few imaging scenarios.

The most basic element of the observation sequences is an individual HiRISE image. **Table 6.3.3a** provides some examples of the types of images that HiRISE is expected to collect. HiRISE is extremely flexible because it has 14 independently commanded CCD arrays. This allows each image to be tailored to the science goals for that observation. We expect that after several months in the PSP (Primary Science Phase), we will develop a set of imaging modes that prove to be most useful, most often. However, we have made no attempt to pre-define these modes.

Table 6.3.3a - Examples of HiRISE Imaging Modes.

The following list is intended to illustrate flexibility of commanding HiRISE, but represents only a fraction of the types of images we expect to collect. Image sizes are computed including all line, channel, and observation headers. FELICS is conservatively assumed to provide 1.7:1 compression.

Example	Potential Science /TAG Objective
A	Maximum resolution search for Lander under poor lighting conditions at high latitude
B	Part of a stereo observation of a potential future landing site
C	Observation of small gullies in a canyon wall and surrounding terrain
D	Investigate possible ice-heave features and their surroundings
E	Color strip used to investigate mixing of color units within a CRISM pixel
F	Image of unusual dunes requested by the public
G	Re-image a MOC strip to search for surface changes
H	Sample unusual terrain seen in THEMIS but not imaged by MOC
I	Sample patch with unusual spectral properties
J	Sample Terrain never imaged at high resolution

	Image size		Downlink Gbits		bits/px	Summing (nxn per CCD)													
	(km, WxL)	(Mpixels)	no comp.	FELICS		R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	IR1	IR2	B1	B2
A	6 x 12	842	12.579	12.579	14	1	1	1	1	1	1	1	1	1	1	0	0	0	0
B	6 x 18	1262	9.462	5.566	8	1	1	1	1	1	1	1	1	1	1	0	0	0	0
C	3.6 x 12	341	2.566	1.509	8	0	0	2	2	1	1	2	2	0	0	2	2	2	2
D	6 x 6	123	0.926	0.544	8	4	4	4	2	1	1	2	4	4	4	0	0	0	0
E	1.2 x 6	127	0.958	0.563	8	0	0	0	0	1	1	0	0	0	0	2	2	2	2
F	3.6 x 6	44	0.338	0.199	8	0	0	4	4	2	2	4	4	0	0	4	4	4	4
G	3 x 30	71	0.541	0.319	8	0	0	4	4	4	4	4	0	0	0	0	0	0	0
H	4.8 x 6	8	0.060	0.036	8	0	16	16	16	4	4	16	16	16	0	16	0	16	0
I	1.2 x 1.2	7	0.051	0.030	8	0	0	0	0	2	2	0	0	0	0	4	4	4	4
J	1.2 x 1.2	0.1	0.001	0.001	8	0	0	0	0	16	16	0	0	0	0	0	0	0	0

Observations may be classified as (1) “stand-alone,” (2) “coordinated,” or (3) “ride-along.” Stand-alone observations do not inherently require any coordination with other instruments. They are image sites where HiRISE data alone are sufficient to answer the scientific question that has been posed. The HiRISE team intends to create, modify, and/or delete stand-alone observations without coordinating with other teams. Coordinated observations are aimed at locations where the synergism between HiRISE and at least one other instrument are needed to address a science question. Coordinated observations are necessarily interactive. Ride-along observations are (relatively) small HiRISE observations taken when another instrument is making what they consider to be a stand-alone observation. The other teams are able to modify and/or delete their observation, at any time, without consulting the HiRISE team (but we appreciate notification).

We expect that for about 80-90% of HiRISE targeted interactive observations it will be desirable scientifically to have simultaneous CRISM coverage. CRISM coverage for nadir imaging will be on an as needed basis, such as when HiRISE is sampling regions with its color CCDs. Simultaneous CTX images will be needed for all stereo targets and on most of the non-stereo, off nadir observations. CTX images will probably be requested for most of the small nadir images, but are not anticipated for the large binned nadirs.

We expect ~5/6 of our off-nadir requests to be less than 9 degrees from nadir. Only 1/6 of our requests (one of two images for each of 1000 stereo targets) will be > 9 degrees, which impacts the global monitoring of MCS.

The individual observations are combined to create the HiRISE observation sequence. In doing so, issues of removing conflicts from the timeline, managing the SSR and computer resources, and assuring a full load for downlink are all balanced. **Appendix A** presents one scenario for 2 typical days of operations in the PSP. One key point that is highlighted in **Appendix A** is that it only takes seconds to acquire a HiRISE image, minutes to clear the buffer so another image can be taken, but hours to packetize and playback data. Thus we expect HiRISE to have a low average duty cycle.

The results of other observation scenarios are compiled in **table 6.3.3b.** The observation scenario varies most strongly with the downlink volume. During low data rate periods, we expect to take a very small number of large images of the most important science sites and a few other small images of other sites. During very high data rate periods, we expect to take larger images to fill the downlink without excessively increasing the number of images. We expect to acquire many small images early in the PSP to sample different terrains at HiRISE resolution. This is essential so we learn what is most informative at these scales so we can intelligently select the small area (up to 1%) of Mars to image at high-resolution.

As a baseline, we expect about 10,000 HiRISE images in the PSP. Of these about 60% will be off-nadir, interactive observations. The remaining 40% will be non-interactive nadir images. Of the off-nadirs, about 1/3 (~2000) will be components of stereo pairs of ~1000 targets. About half of the nadir observations (~2000) will be small image samples, with the other half being large binned images.

The binning mode used will depend on spacecraft jitter characteristics, camera PSF, data volume margins, surface geology, surface albedo (SNR), and other factors. A strawman estimate is that of the 2000 anticipated stereo observations, about half will consist of unbinned red CCDs combined with 2x2 binned color observations. The other half will use just the red CCDs with 2x2 binning. Non-stereo off-nadirs will probably be about half unbinned, 25% 2x2 binned, and 25% binned at other values (3x3, 4x4, 8x8, etc.). Given the current lack of a high-stability nadir option in the ITL, most or all nadir images will be binned. The small nadir images will probably be binned at 2x2 or 3x3, with the large nadir images being binned at 3x3 or 4x4 8x8 and 16x16 binning can usually only be used under dim illumination, to avoid saturation. If a nadir high-stability mode is eventually put in the ITL, or if HiRISE acquires a nadir target using a very small slew close to 0°, it will be possible to have some unbinned nadir images. This would probably be on the order of 10% of all nadir targets. Overall, about half of HiRISE observations are anticipated to have color. In all but the highest albedo terrains under good illumination, these will be binned 2x2 or more.

Optimum geometry to produce DEMs requires stereo baseline angles of 15-25°. We prefer to look where phase angles and shadows are greater, which at non-polar latitudes is west. Therefore, at non-polar latitudes we'll try to have the emission angle of the 1st component of each stereo pair be small and looking either east or west, with the 2nd component being larger and looking west. Due to the low incidence angles and variable direction of the Sun in polar regions, the criterion for stereo images here is not dependent on cardinal direction but rather on having a pair of images with good phase angles and stereo baseline angle and consistent illumination angles. In most cases stereo observations will require one component >9°. It will be rare to have both greater or less than 9°.

The amount of time delay and integration (TDI) lines will depend on binning mode (which is also a function of the as yet undetermined spacecraft jitter characteristics) and the intensity of the scene. An increase in binning often requires a corresponding decrease in TDI to avoid saturation (e.g., 1x1 at 128 TDI over a bright scene would go to 2x2 at 32 TDI or 4x4 at 8 TDI). For many Mars scenes, the TDI mode will follow this simple rule. However, very bright or dark scenes and use of the BG and NIR CCDs will make the choices more complex. The TDI lines for a given binning mode can be reduced, sacrificing SNR, if jitter-induced smear is a concern. Co-I Nick Thomas is currently working on a photometric mode to optimize the choice of TDI lines and binning modes as a function of scene intensity.

All but a small percent of HiRISE images will be converted from 14- to 8-bit via onboard lookup tables (LUTs). It's anticipated that 14-bit will be used for some color images to get good NIR/red/blue-green ratios and scenes where the dynamic range and histogram are not well understood. Nick Thomas' photometric model will be used to predict the optimal LUT table as a function of instrument operating modes and viewing conditions (albedo, TDI, binning mode, etc.). Note that we will be using nonlinear LUTS, with greater compression of both the bright and dark wings of the histogram. This enables preservation of data precision over the majority of the image with minimal risk of saturation. However, it will also result in "strange" brightness distributions so application of the calibration program HiCal will be essential.

Table 6.3.3b – Summary of HiRISE Orbital Activities Scenarios

The following table summarizes some reasonable observation scenarios but cannot capture the full scope of HiRISE capabilities

Data Rate Period	Low	Average	High	Peak
Typical HiRISE Downlink availability (Gb/day)	4.5 – 9	9 -16	16 - 32	32 - 48
Percent of time at this data rate	~30%	>40%	~25%	<5%
Typical number of HiRISE Observations per day	2 – 5	5 – 15	10 - 30	10 - 40
Typical size of HiRISE observations (Gb)	0.01 – 16	0.01 – 16	0.01 – 18	.0.01 – 20
Typical peak load on HiRISE SSR partition (Gb)	4 -16	5 – 20	10 – 28	15 - 35
Typical HiRISE volume on SSR awaiting playback (Gb)	3 – 16	5 – 30	10 – 35	15 – 35
Typical number of Interactive Observations per day	0 – 1	1 – 4	2 – 10	4 – 15
Typical number of images coordinated with CRISM only per day	0 – 1	0 – 1	0 – 2	0 – 2
Typical number of images coordinated with CTX only per day	0 – 4	1 – 10	5 – 20	10 – 30
Typical number of images coordinated with CRISM and CTX	0 – 2	2 – 5	5 – 10	10 – 20
Typical number of ride-along images per day	0 – 2	2 – 5	5 – 10	5 - 15

6.3.4 Command Load Generation

During the PSP, HiROC will have three full-time Targeting Specialists to oversee and carry out targeting and observation sequence planning. The Targeting Specialists work with the Co-I-of-the-month lead to ensure the science and operational objectives are met. Each Targeting Specialist will have the scientific knowledge and practical experience to design observation sequences that accommodate Mars viewing conditions and spacecraft and instrument operational constraints. The Targeting Specialists work with the E/PO lead to coordinate the weekly observation in support of E/PO activities.

Downtrack and crosstrack orbit uncertainties preclude nadir observation planning beyond a one-week period. The Targeting Specialist is responsible for planning nadir observations and working with the Investigation Scientist to coordinate requests with the CTX and CRISM teams, if coordination is desired. The Investigation Scientist will work with the Co-I-of-the-month and the Targeting Specialist to coordinate cross-team joint observations and will review plans for compliance with agreements reached at the TAG.

HiPlan is a software tool for planning observation sequences at HiROC. By negotiating a cooperative agreement with the THEMIS group at ASU, we expect to build on MTT, which in turn is built on the THEMIS targeting tool JMARS. It will initially use navigation data and the HiCat candidate target list to identify the highest-priority targets within ~30 deg of the groundtrack. The Co-I has the opportunity to select specific targets to be acquired for the coming month using HiPlan. The Targeting Specialist will design the final sequences using HiPlan and Data Tracking Tool (DTT), a project-provided tool that will be used to model onboard data flow and manage HiRISE data volume on the SSR. Running HiPlan and DTT the Targeting Specialist or Co-I will choose camera parameters to optimize SNR and match data volume to camera memory, S/C memory, and downlink capability.

Prior to the final commands for a week being radiated to the spacecraft, HiROC staff will review and, if necessary, modify the observational sequences based on improved predict navigation data or changing atmospheric conditions. Camera configuration commands are then generated and checked one last time against operational limits by HiCommand and sent to JPL via the SOPC (see **table 6.3.4** for uplink deliverables.

Table 6.3.4 - Uplink Deliverables

Uplink Product	Delivery Frequency
Off-nadir target requests (PTF)	Monthly
Off-nadir image command blocks	Monthly
Nadir target requests (PTF)	Weekly
Nadir image command blocks	Weekly

To summarize, Targeting Specialist duties include (1) creating HiRISE sequences, (2) checking observation sequences against operational constraints of the spacecraft and instrument, (3) creating and verifying command loads for uplink to the spacecraft, (4) modifying sequences and command loads to reflect changing viewing conditions on Mars, (5) working with JPL/MRO operations staff when uplink data flow problems occur, and (6) assisting in the population of the image suggestion database. The HiRISE-supported post-doctorate researchers and graduate students at the UA will be trained to additionally perform target sequencing. These individuals will act as backup to the Targeting Specialists. The schedule of activities for the three Targeting Specialists is shown in **figure 6.3.4.**

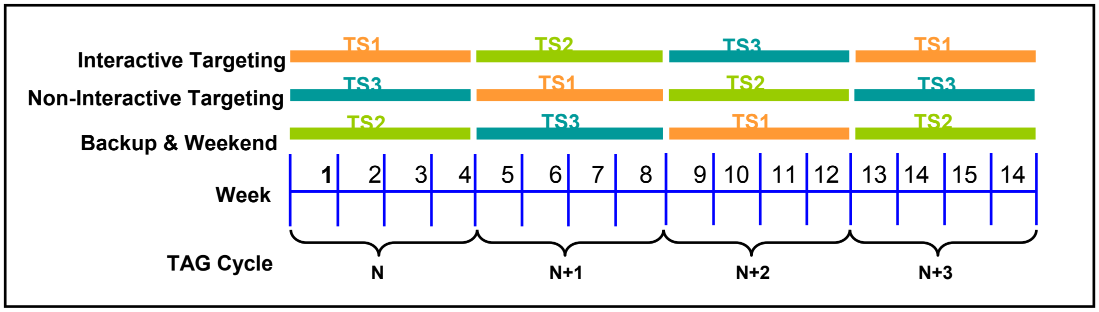

Figure 6.3.4. - Activity schedule for the three targeting specialists is tied to the 28-day TAG planning cycle. During TAG cycle "N" targeting specialist TS1 is responsible for managing the interactive targeting development and working directly with the TAG team on the upcoming cycle. Targeting specialist TS3 is responsible for carrying out non-interactive (nadir) targeting for the cycle being executed. Targeting specialist T2 acts as backup and carries out the limited targeting and uplink commanding during the weekend. For TAG cycle N+1 the responsibilities shift as shown in the chart.

6.4 Downlink Processes

The objective of the HiRISE downlink process is to retrieve data from MRO operations center at JPL then produce and validate the products that can be shared with users (the HiRISE science team, other MRO investigators, the Mars Exploration Program, the Mars science community, and the general public). These downlink activities will be centered at the HiROC on the University of Arizona campus. HiROC will use automated processing to create raw and processed HiRISE images in a timely fashion. This automated processing will take advantage of the Conductor process (completed in mid-2003) which allows the construction of processing jobs based on information in the HiCat database. Unless there are problems with telemetry packets or navigation data, images will be available to scientists and the public within weeks of HiROC receiving all the necessary image and ancillary data.

6.4.1 Interface with MRO Project Facilities

The data processing begins when the downlink organizer (HiDOg) retrieves science data from the project's Raw Science Data Server (RSDS) at JPL and delivers them to HiCat. The data on the RSDS will be organized into files that correspond to an individual HiRISE observation, unless a waiver is accepted to organize the data by channel (up to 28 channels per observation). The science data stream includes a unique 32-bit ID that was generated during the sequence planning stage assuring a link between the downlink science data and the uplink commanded observation. Using the CCSDS File Delivery Protocol Subsystem (CFDP), the MRO Ground Data System at JPL will be responsible for "depacketizing" the data to form files that represent the science data stream as it was delivered to the spacecraft by the instrument. For HiRISE observations the science data stream will be either uncompressed or compressed by the onboard FELICS compressor. The CFDP subsystem will create an "accounting file" that identifies the locations and lengths of gaps found in the instrument data stream due to telemetry transmission problems. The science data file is also accompanied by a PDS label providing additional identification and metadata about the file. Partial deliveries of the science data file will be available nominally at 24 hour intervals. The partial deliveries allow HiROC the ability to evaluate an observation before all data associated with the observation has been received at JPL. During periods of low volume data return, it could take several days to retrieve all of the data associated with an observation. The science data file will be considered "final" when no new data have been received by the DSN for a designated time interval. This time interval can be adjusted during the mission, but will often be a few days in duration. During periods with low data rates, it may be extended even further.

The CFDP "accounting" file will be automatically pushed to HiROC by the RSDS using the File Exchange Interface (FEI) system whenever a new file is generated (*i.e.,* a timer has clocked-out). Upon receipt of the file, FEI spawns HiDOg to interrogate it (i.e., sniff it out). Based on criteria set by the HiROC staff, the procedure will then be to download it immediately or defer transmission of the file when it is complete. An example of these criteria might be "download only if there is at least 25% more of the observation or if this is the final version of the observation file." The science data file will be stored on HiCat's file server system for later use. Metadata about the observation (including the success or failure of the download and the precise location of the file) will be placed into HiCat. Ancillary data will also be pushed to HiROC via the FEI process and be automatically recorded in HiCat upon arrival.

6.4.2 Automated Processing

After downloading the raw science data file for an observation, the data are then handed to HiProc for automated processing. The first step, EDRgen, generates PDS-labeled EDR products. This step includes (1) image decompression and accommodating data gaps, (2) organizing the image data by CCD, (3) extraction of information needed for the PDS labels, and (4) storing additional metadata in PDS objects within the EDR file. Later steps will produce binned and full-resolution RDR products in PDS format. The latter processing steps will rely on the ISIS image processing package released by the USGS. The processing steps will include (1) radiometric correction, (2) geometric transformation to standard map projections, (3) formatting data to PDS standards, and (4) preparation of data products for HiWeb by providing lossless JPEG2000 compression. Data Processing Specialists will monitor the processing of each image to ensure that they are executing properly. The products will undergo verification and validation as each HiRISE data product is produced (see **section 6.4.3**).

EDRgen will create raw images (EDRs) within hours of receiving data from the RSDS. The first data processing step decompresses the image data, if FELICS compression was applied onboard the spacecraft. While the software (including source code) to decompress FELICS will be provided to HiROC, we will have to develop the software to handle the data gaps. Once decompressed, each HiRISE observation consists of data from up to 28 channels (2 per CCD), clearly delineated by channel headers. The raw data will be archived with separate files for each CCD. This will require the juxtaposition of the image data from the two channels of each CCD (one of which is flipped left-right) and the separate handling of the dark current pixels at the end of each line. We can also run HiStitch to quickly make an image from the output of all the CCDs commanded in the observation.

Generation of the RDR products will require the incorporation of reconstructed SPICE (Spacecraft and Planet ephemeredes, Instrument, C-matrix, and Event) kernels generated by the MRO navigation team typically within a short time after data acquisition. We expect that the problems discovered in the raw images will have been corrected by this time and processed images will be produced within a week of receipt of reconstructed SPICE data.

Two levels of processing are planned resulting in binned and full-resolution RDR products. The distinction is the resolution of the image and whether the HiJitter process was applied to the imaging to improve geometric fidelity of the image correction. Both types of products will be radiometrically corrected and reprojected to a standard map projection. HiJitter corrects for the motion of the spacecraft during the acquisition of the highest resolution images. As such, the binned products will be at least 2x2 averaged. Also, for color products, the largest level of binning will be used for the final product. This minimizes the need for careful co-registration of the different color data that have experienced spacecraft jitter effects. A table will be developed to compute what binning mode(s) to use for the binned RDR product(s) given an original observation with multiple binning modes. We expect the HiJitter program may require a one year research and development, after we are in orbit, to sufficiently understand the spacecraft jitter and best analysis techniques and to create the full resolution RDR products.

Immediately after validation of the binned RDR products, the EDR and completed RDR products will be made available via HiWeb. Before this can be accomplished, the RDR images will be losslessly compressed using JPEG2000. This will reduce our data storage needs and greatly facilitate distribution of the data over the web (see **section 8.4** for more details).

The HiRISE team will also produce smaller volumes of more highly processed data products. These include press release images with captions provided weekly to the MRO project and HiWeb. This work will not involve automated processing and will be the responsibility of Co-Is and post-docs.

6.4.3 Data Verification and Validation

All HiRISE products will undergo verification and validation before release. Verification will be a step within the automated processing. Key values (e.g., number of lines) will be extracted from the processed product and compared to the value expected based on data in HiCat. Any discrepancies will be flagged for human attention. The validation will require humans examining the product to assure that the final product is of appropriate quality. While the validation will be the responsibility of the Data Processing Specialists, they will be assisted by the Co-I's and supervised student interns. A training program will be developed for all data validators and a graphical user interface will assure that all items are checked systematically. The results of the validation (along with the name of the validator and the date of the validation) will be automatically recorded in HiCat. The automated processing (or release) of the product can only proceed after a "success" validation flag is found in HiCat.

6.5 Monitoring Instrument Health

6.5.1 Routine Operations

The Ball Aerospace engineering team will continue to support the HiRISE science team throughout Phase-E (the “HiRISE Engineering Support Team (HiEST)” referred to in subsequent paragraphs will consist of Ball engineers and the DPI). The HiEST role will be to monitor instrument health and performance, analyze anomalies, and design sequences for camera engineering needs such as focus mechanism adjustment or software patches. For most of the mission the HiEST staffing levels will be part-time or on-call.

Camera engineering data (temperatures, voltages, etc.) are downlinked with channelized spacecraft engineering telemetry, decommutated at JPL, transferred to the HiROC SOPC, analyzed and archived. Most of these data are also returned in the camera science data header along with other supporting data including the Look-Up Table (LUT) settings which are used to convert 14-bit image data to 8 bits. Additional data important to camera performance analysis (dark current) are contained in the image in the masked pixels at the end of each image line.

Starting with cruise (when the camera is powered on), through the PSP, HiROC staff will routinely monitor science and engineering data. The SOPC-provided Data Monitor and Display program (DMD) will be configured to automatically scan the HiRISE engineering data for acceptable levels and operating limits of the instrument. Alarms will be triggered whenever operational limits are exceeded. The HiROC staff will contact the HiEST lead (A. Delamere) when problems are detected. The additional science data stream containing the masked pixel data will be evaluated as part of the science processing and visual inspection process. HiROC operations staff will be trained to recognize instrument problems by the Ball engineers who developed the instrument.

The HiEST is responsible for analyzing the engineering data to evaluate the health and performance of the instrument. The HiEST system engineer (J. Bergstrom) will access the data through HiROC, running a routine daily procedure to pull engineering data and image sub-scenes, Monday through Friday. He will publish a simple weekly report with trend analysis, any anomaly conditions encountered, and results of special activities such as stimulation lamp images or focus mechanism adjustments.

HiRISE will periodically acquire stimulation lamp images when the spacecraft is on the night side of Mars. The HiROC team will generate the stimulation lamp image sequences using HiCommand. The HiEST will analyze the data.

HiROC staff will generate all routine image sequences (as described previously). Any command sequences other than normal image acquisition commands will be input into the project background sequence planning by the HiRISE IS, the commands will be generated by HiEST using SEQGEN, and will be integrated in the background sequence by the MRO Sequence Integration Engineer (SIE). HiEST will review all background sequences containing non-image commands.

6.5.2 Critical Periods and Calibrations

Critical periods include:

- Camera power on
- Thermal stabilization, functional checkout (including dark current and stimulation lamp images)
- First target image acquisition (Moon / Omega Centauri)
- Focus adjustment + star tracker alignment (M11)
- Detailed focus test, geometric calibration and jitter test (M45)
- Post-MOI imaging
- Transition orbit imaging
- First images in Primary Science Orbit.

The HiEST will design the camera sequences for these activities, run SEQGEN, review uplink products to ensure their correctness, and analyze the downlinked data. The full group will be on hand for each of these events, with some individuals at HiROC.

The HiEST will work with the HiRISE science team, IS, and LMA spacecraft team to schedule and develop cruise, transition phase and twice–per-year star calibration sequences in the PSP. The HiEST will analyze the images and publish reports with the results (for example the best focus mechanism setting).

In the event that new look-up tables (LUTs) need to be loaded the science team will define the content of the new LUT. The HiEST will test the new LUT on the ground and then create the required command sequence to uplink the new LUT.

6.5.3 Anomaly Response

HiROC staff will report alarms and any anomalies in the image data to the HiEST lead. The HiEST lead will assess the criticality of the anomaly and call in other members of the group as dictated by the nature of the anomaly. The HiEST will recommend diagnostic actions (e.g. memory readout), recovery activity, and if necessary alternative camera operation procedures to avoid future occurrences of the problem.

6.5.4 Software Patches

In the event of HiRISE flight software problems, the HiEST software engineer will be responsible for analyzing problems and generating patches for the onboard system. The HiEST and the HiRISE science team will jointly test and evaluate the software changes. The HiEST will work directly with LMA to get software updates uploaded and configured on the instrument.

6.6 Phase-C/D Activities

6.6.1 ATLO

The primary purpose of ATLO is to test the functionality of the instrument and its successful operation through the spacecraft, both to respond to commands and to flow data through the spacecraft data system. A secondary benefit is to test the ground data system.

Prior to integration on the spacecraft HiRISE will be commanded using MRO_HIRISE_SIM, a tool developed by Ball. During the initial test and integration phase at LMA we will transition to using SEQGEN to issue commands to the instrument through the spacecraft C&DH. (The MRO SEQGEN adaptation is built from the command dictionary by LMA, and includes HiRISE commands.) We will have a standard functional test that can be run on the spacecraft to check out HiRISE before and after each spacecraft test. Other tests of HiRISE that are required in ATLO are described in detail in the HiRISE "ATLO Plan" document.

The LMA ATLO team will run a series of Sequence Verification Tests (SVT) that are executed from a sequence running on the spacecraft (as compared to a series of individual commands issued from the test console). The HiRISE IS will attend planning meetings as appropriate. The HiRISE team will supply camera commands in HiRISE image sequences, as planned for the PSP. This drives the schedule for a stand-alone version of HiCommand.

Data access will be local (at LMA) and remote at HiROC. Near-realtime engineering data will be monitored on workstations at LMA using DMD to display data. All data will be stored locally on a file server that can be accessed by the HiRISE team on-site at LMA for ATLO. The data will also be transmitted to JPL to the RSDS. From there we will test HiROC data access via FEI. HiRISE data will be archived at HiROC. This drives the schedule for development of HiCat, EDRgen, DeFELICS, and Conductor.

6.6.2 Pre-Launch Project-provided Training

The project will provide (and HiRISE will participate in) training in the form of presentations on system, subsystem, processes and events; workshops; rehearsals of processes and timeline activities; and Operational Readiness Tests (ORTs).

According to Ruth Fragoso, the MRO trainer, training presentations and tutorials will take place from January to December 2004. The topics include: MRO Overview, Subsystem Tutorials (spacecraft and instruments), Uplink Processes, Downlink Processes, Security Briefings and Anomaly Response Process.

Workshops in the same time frame include: Workstation training (Unix, DMD, and T/M data flow), SOPC training, DOM training, Sequence Product Development, and Voice Net Protocol.

Rehearsals of various processes and thread tests are scheduled from February to June 2005. Emphasis is placed on the exchange of products, expected tasks, personnel and procedures. Three rehearsals are currently planned:

- IPTF Generation: Interactive observations (HiRISE will generate and submit PTFs and exclusion zones, POST identifies conflicts, the timeline is iterated, and the TAG will meet)
- IPTF Modification: Non-interactive Observations (POST will provide instrument teams with PTFs, HiRISE will add nadir observations and return PTF, POST merges PTFs, and generates ITL, command conference and radiation)
- Realtime command generation process (HiRISE will generate NIFL(s) using HiCommand).

6.6.3 Operational Readiness Tests

Operational readiness tests are as flight-like as possible, including following a flight-like timeline. MRO will carry out an ORT of the 28 day sequence planning cycle which will include three weeks of sequence development and 1 week of execution. HiRISE will supply the PTFs required and camera configuration NIFL's. A 9/29/03 email from Carl Kloss suggests that there will be an ORT for cruise operations on 15 May 2005.

HiRISE will need the project to repeat a subset of these training activities when the operations team is staffed in 2006. Prior to that the software developers and science team will attend the tutorials and participate in the rehearsals.

6.7 Inflight Calibration

Inflight calibration observations will be acquired to (1) Evaluate the performance of HiRISE, (2) to determine how the instrument radiometric and geometric calibration has changed in a post-launch environment, (3) to assess the effects of spacecraft jitter under a range of conditions, and (4) to determine the boresight alignment between HiRISE and the star trackers, CRISM, and CTX. These calibrations will occur during cruise and in the aerobraking, transition, and in primary science orbits. More details are contained in the HiRISE Calibration Plan.

6.7.1 Cruise Calibrations

Three observation periods are planned during cruise. The images will be large and uncompressed, commonly up to 60,000 lines that will fill the memory buffers. All slews will be at 0.05° sec^{-1}, necessitating a line time of 1.1 msec. IMU data at 200 Hz. and quaternions at 10 Hz will be downlinked simultaneously with all calibration images. In addition, these ancillary data will be acquired independent of imaging in order to assess the stability of the spacecraft under various conditions (reaction wheel speed, solar array movement, etc.).

<u>Lunar and star calibrations are planned for September 8, 2005</u>: During this opportunity, there will be at least three scans across the Moon to the globular cluster Omega Centauri. These will be the first HiRISE images taken in space. Each scan will be at a different focus position, with one of the scans at the predicted best focus and the other two offset from this on either side. The inner CCDs, including color, will be set at 8 TDI lines, full resolution, 14 bit, to best acquire lunar radiometric data. The other CCDs will be set to 128 TDI to image stars. As HiRISE slews toward and away from the Moon, observations of space will be acquired for later analysis for dark current and scattered light. These data will be downlinked as MRO continues its slew to Omega Centauri. The CCDs will be turned on again to image Omega Centauri at 128 TDI and 14 bit, probably with some of the color CCDs.

Star Tracker-to-HiRISE and star calibrations on launch + 54 days: During this opportunity, HiRISE will make several scans across the globular cluster M11 at different focus positions. Imaging will be at 128 TDI and 14 bit, probably with some color. The timing of stars passing through the HiRISE CCD lines will be compared to the timing and position of stars as seen by the Star Tracker (ST). These data will be used to calibrate the boresights of the STs to HiRISE. Relative star positions will also be used to provide a preliminary assessment of geometric distortion and jitter. Depending on focus, PSF may also be measured (the best measurements of geometric, jitter, and PSF comes in Dec. 2005). Observations of dark space will be used to assess dark current.

Star Calibrations in December, 2005: These calibrations will occur on two days separated by about a week and will view the open cluster M45 (Pleiades). In the first opportunity, several focus positions will be tested. These data will be downlinked, after which no more than a week will be spent determining the best focus. This focus position will then be uplinked and used in twelve or so calibrations to assess geometric, PSF, and jitter. The jitter tests will involve the activation of various spacecraft components (CRISM cryocooler, MCS, etc.) to build up a matrix of noise sources. Imaged areas of dark space will be used to assess dark current.

In addition to these cruise opportunities, HiRISE plans to operate the stimulation lamps under various operating temperatures and modes to evaluate the relative radiometric changes of the instrument after launch.

6.7.2 Aerobraking Orbit Calibrations

HiRISE would benefit tremendously from a few observations during early aerobraking. This will provide enough time for the team to evaluate jitter sources and develop the HiJitter software before entering the Transition Orbit and PSP. Aerobraking observations are particularly critical given the essential role that HiRISE will play in Phoenix landing site selection. This lander is targeting the near-north polar region, latitudes that are best illuminated in the early PSP. We therefore request that the Project allow aerobraking images to ensure that the jitter contribution in unbinned HiRISE images be understood by late 2006.

6.7.3 Transition Orbit Calibrations

The primary goals of HiRISE's transition orbit calibrations are (1) demonstrate that we can get good images of Mars, (2) acquire targets interactively using a HiRISE PTF and spacecraft ITL, (3) determine boresight alignment with CTX and CRISM, and (4) assess spacecraft jitter. The jitter tests will involve a matrix of noise sources similar to and expanding upon those acquired with stars in Dec. 2005. The jitter test images will be acquired simultaneously with 200 Hz IMU and 10 Hz quaternion ancillary data. HiRISE urges that the Project allow some nadir imaging during solar conjunction as well.

6.7.4 Primary Science Orbit Calibrations

Ideally, all major inflight calibrations will be achieved before the start of the PSP. If jitter is still not well understood at this time (as seems very likely), then more jitter calibration imaging under appropriate spacecraft and instrument operating conditions will be required. All images of Mars will be associated with simultaneous 200 Hz IMU and 10 Hz quaternion ancillary data. This information, combined with analysis of pixel displacement in the CCD overlap regions, will be used to assess jitter. Because the spacecraft will be in various noise states as conditions change, analysis of specific images that coincide with these states will allow a much fuller understanding of jitter than was possible during the Transition Orbit. Observations with the stimulation lamps turned on will be acquired on the dark side of Mars in order to monitor relative changes of the instrument. Dark current will be acquired on the same orbit by imaging the night side. In the beginning of the PSP, dark current will be measured about once per week, later decreasing to about once per month or after any solar flare event. Geometric, PSF, and focus tests using stars will be conducted every 6 months, generally using the same clusters as in cruise. These observations will also provide stray light calibrations as HiRISE is slewed off of Mars. Radiometric and stray light calibrations of Phobos and Deimos will be conducted as opportunities warrant (CRISM has given Phobos and Deimos observations a high priority and HiRISE will coordinate with these observations). While in orbit about Mars simultaneous observations with the Hubble Space Telescope (HST) and ground-based observations are planned. Comparison between HiRISE and HST imaging will achieve absolute radiometric calibration within the 20% requirement. Dust storm observations and use of averages of the bland regions (at scales roughly equivalent to the HiRISE FOV) in many HiRISE images will be used as flat-fields in order to evaluate the relative performance of the instrument detectors. Simultaneous observations with the CTX and CRISM instruments will also be used to monitor radiometric performance.

7 SCIENCE DATA PROCESSING PLAN

7.1 Distributed Science Analysis

To support HiRISE data analysis requirements, the Science Team will be equipped with data processing computers (see **section 10.4)** configured with the ISIS system. Sufficient computer resources will be available at their home institutions to support the research needs of both the Co-I and associate researcher. The HiROC system administrators will support the initial installation and configuration of the Co-I computers. The ISIS system will be periodically updated and distributed to the Co-I computers through an automated system already developed by the USGS. ISIS training will be available to team members during the cruise phase of the mission. Some Co-Is will use additional software systems, such as IDL, that will support their research activities. These supplemental software systems are expected to be developed outside the scope of HiROC support tasks and will be developed within the scope of the Co-Is research activities. Science team members will be able to access HiRISE products through the HiWeb system. Additionally, Co-Is will be able to order large data volumes for surface shipment.

7.2 Image Processing

The Integrated Software for Imagers and Spectrometers (ISIS) system will be used by the Science Team, and the HiROC automated processing procedures for creating standard data products. ISIS (see http://wwwflag.wr.usgs.gov/isis-bin/isis.cgi) will be adapted to handle the instrument specific requirements of HiRISE for radiometric correction and geometric processing. ISIS, the workhorse for the USGS planetary cartography effort, supports processing for data sets from past and present Mars missions including Mars Odyssey, MGS, Mars Pathfinder, Viking, and Mariner 9. The ISIS components directly applicable to HiRISE include map projection transformation, image mosaicking, camera pointing correction, and general image enhancement, display, and analysis tools. The HiRISE processing capabilities added to ISIS will be freely available to the science community through the USGS commitment to periodic distribution of ISIS. Scientists will be able to perform specialized cartographic and image processing of HiRISE data at their home institutions by becoming registered ISIS users.

7.3 DEM Production

Digital elevation models (DEM's) and derived products will be produced by the US Geological Survey (Planetary Geomatics Group of the Astrogeology Team) in Flagstaff Arizona, which has experience in planetary stereomapping extending back to the 1970s. Techniques for digital (softcopy) mapping were developed in the late 1990s and have been applied successfully to a wide variety of datasets, yielding, among other things, an experience base used in generating the HiRISE DEM staffing plan and budget.

Our approach to digital stereomapping has been successfully demonstrated for stereo imaging from the Mars Pathfinder mission, Clementine, Mars Global Surveyor/MOC, and Viking Orbiter. The work is most similar to these projects involving images from orbit but there are significant differences as well.

The essence of the USGS approach to planetary stereomapping is the synergistic use of the in-house image processing and planetary cartography system ISIS and BAE Systems' commercial digital photogrammetric software SOCET SET (SOftCopy Exploitation ToolSET). ISIS, which will be used for processing of HiRISE data, is used for "two-dimensional" image-processing steps such as map projection and mosaicking and particularly mission-specific processing such as ingestion and radiometric calibration of images. Development of ISIS in-house ensures that these steps can be tailored to specific mission needs as required. SOCET SET is used for intrinsically "three-dimensional" steps. The most important of these are DEM production by automatic image matching and DEM quality control and interactive editing involving overlay of DEM data (points, mesh, or contours) on the images in an optoelectronic stereo display and user input via a three-dimensional hand controller. SOCET SET also provides tools for automatic and manual selection of control points and bundle-adjustment to refine image pointing data based on these points, as well as manipulation of DEM data such as contouring, relief-shading, and orthorectification (parallax removal) of images based on the DEM. Other software packages such as ESRI ArcView GIS and Adobe Illustrator may be used to produce finished map products with grids, scales, and appropriate annotation from the DEMs and rectified images.

SOCET SET does not intrinsically have the ability to read planetary spacecraft images. We have therefore used the Developer's Toolkit (DevKit) to write a set of translator programs needed to bring images (including the geometric metadata in their labels) from ISIS into SOCET SET and to export DEMs, orthorectified images and mosaics, and other products from SOCET SET for further processing in ISIS. We have also used the DevKit to create "sensor model" software needed for SOCET SET to understand the geometric properties of Magellan synthetic aperture radar images so that we can make stereo maps of Venus. A similar effort to develop a sensor model for HiRISE is not necessary, because the "generic pushbroom scanner" model can be used to describe the instrument. We need only write the translation software to read a HiRISE ISIS cube and write a SOCET support file containing the information needed by the generic scanner model. We have recently developed such a translator for the MGS MOC wide- and narrow-angle cameras, permitting us to make high-resolution DEMs and maps. Note that we have been guilty in the past of contributing to possible confusion about the accuracy this sensor model. It is a rigorous physical model of the operation of a pushbroom scanner ("generic" with respect to quantities such as sensor size, field of view, etc.) and should not be confused with non-rigorous models that can approximate the behavior of any sensor by fitting rational polynomials to a large amount of ground control data.

The capabilities of the stereomatching software, along with the geometric properties and scene content of the images, determine the precision and resolution of the output DEMs. The performance of Automatic Terrain Extraction (ATE) is comparable to that of other stereomatching software. It incorporates an area-based matcher and performs multiple passes working generally from resampled, reduced-resolution versions of the images toward full resolution and from coarse DEM post spacing to fine. The matching window in the final pass is typically 5x5 or 3x3 pixels, and, although posts can be spaced as closely as desired, they will not resolve topographic features smaller than this final window size. We plan to produce HiRISE DEMs with a post spacing of 4 pixels, i.e., 1–2 m. The vertical precision of the measurements depends on the convergence angle of the images, the image resolution, and the matching error. A widely used estimate of stereo matching error for many types of images is 0.2 pixels. Our Mars Pathfinder experience confirms that this is achievable with ATE. For a stereopair containing one vertical image and one with an emission angle of 20° the expected vertical precision (EP) is about 0.5 pixel.

Increasing the obliquity of one or both images will improve (reduce) the EP statistic but image matching could fail if the images are too oblique (so that slopes are severely foreshortened or even hidden) or the phase-angle difference between the images becomes too large. Given that EP is already substantially less than the effective horizontal resolution of the DEMs and further improvement only exacerbates this mismatch, a convergence angle of 20° is likely to be near-optimal for stereo imaging with HiRISE.

The resulting expected vertical precision of HiRISE DEMs will, at 0.1–0.2 m, actually be superior to MOLA. The absolute accuracy, however, will be limited by our ability to tie the stereomodels to ground control. The ultimate source of both horizontal and vertical control is MOLA, which has absolute accuracy ≤1 m vertically but ~100 m horizontally, 300-m spot spacing along tracks, and numerous gaps ≥1 km between adjacent tracks. Because of the low horizontal resolution of the MOLA dataset compared to HiRISE images, vertical accuracy will likely be governed by the difference between localized topographic features and the broader-scale relief as measured by the altimetry, and may be as poor as several meters, which is still so small that geologic interpretation of the data is not compromised. The resolution mismatch between the two datasets is likely to make *direct* use of MOLA for horizontal control almost impossible. Our approach is to control lower resolution images to a shaded relief product generated from MOLA data grided at (say) 1/256° or ~231 m/pixel, then to transfer control from these images to the high resolution stereopair. Both Viking Orbiter and MGS MOC wide-angle data cover Mars globally at 200–300 m/pixel. The absolute horizontal accuracy of DEMs controlled in this manner will probably be between 100 m (the accuracy of MOLA) and 200 m. Should it be desirable to produce larger DEMs from multiple overlapping HiRISE stereopairs, the relative errors between the adjacent sections of the model will be much smaller, comparable to the HiRISE image resolution.

Estimated staffing and budget needed to produce DEMs from HiRISE image pairs are summarized below. Our experience with Mars Pathfinder, Viking Orbiter, Clementine, Magellan, NEAR, and MGS MOC images allows us to identify the key steps in production (see below), and provides a reasonable basis for estimating the effort required to process HiRISE data. The effort for most of the steps is the same for the full resolution and partly sub-sampled stereopairs; only the DEM extraction and editing steps are less time consuming for the sub-sampled data.

<u>Preparation:</u> This includes identifying and collecting the necessary data, (HiRISE images, MOLA data, and intermediate resolution control images), ingesting the images into ISIS and performing initial steps such as radiometric calibration, and translating the needed data into SOCET SET format. This step can be formidable for missions such as Viking, which produced large numbers of small images that overlap in a complex way. For HiRISE, the pair of images to be used is known, and identifying monoscopic MOC or Viking coverage of the same area is straightforward. A "high" resolution (1/256°) MOLA DEM and shaded relief map must be produced as well. A total of 5 hours work by a senior photogrammetrist in consultation with Kirk is allocated for these preparatory steps.

<u>Control Point Selection:</u> The intermediate-resolution image(s) must be tied to the MOLA data and the HiRISE stereopair tied horizontally to the images and elevations assigned to the image points based on MOLA. A few tens of points must be measured at each step, but they must be well distributed across the area to be mapped. Searching the extremely large images for suitable features will require more time per point than for many of the images we have used in the past. Eight hours work by a photogrammetric technician is therefore allocated.

<u>Control Calculation:</u> A bundle-adjustment calculation must be performed by using the multi-sensor triangulation (MST) module of SOCET SET, with the image and MOLA measurements from the last step as input. This is a least-squares estimate of improved spacecraft position and pointing parameters. The

actual computation time for a local control solution with a few tens of points and only a few images is negligible, but in practice an acceptable solution is hardly ever achieved on the first attempt. Residuals to the solution will indicate (sometimes ambiguously) the presence of erroneous image measurements, so it will be necessary to iterate between reexamining the measurements and rerunning the adjustment calculation until a satisfactory solution is obtained. The criteria of such a solution are low RMS residuals, absence of "outliers" with larger residuals, and good horizontal and vertical agreement between the images and contours from the MOLA data when overlaid together on the stereo display. On occasion the need to further improve the control solution may even be indicated by comparison of the extracted DEM with the MOLA data. Because the quality of the image measurements has a critical impact on the accuracy of control, remeasurements at this step are performed by senior staff. A total of 16 hours effort by a senior photogrammetrist in consultation with Kirk is allocated.

<u>DEM Creation:</u> The SOCET SET ATE module is used to create a DEM from the HiRISE stereopair. This process can be run in batch mode and takes about 30 hours on a 440 MHz Sun Ultra 10 workstation at present; it is a safe assumption that substantially faster hardware will be available during the MRO mission. The only interactive work needed is to outline the polygonal regions for which DEMs are desired by using the stereo display and 3D input device. For the partly sub-sampled images, DEMs will be collected separately for the full resolution and reduced resolution portions of the images. The few minutes of interactive work in this step can be ignored in the overall staff plan.

<u>DEM Quality Control and Editing:</u> This is a key step in the production process, among the most time consuming and that for which our estimates are least secure because it is extremely dependent on the content, size, and noise properties of the images. One factor is clear: the time spent editing DEMs will be proportional to the number of DEM posts, and the HiRISE DEMs are extremely large (50 million posts for a full-resolution stereopair, 12.5 million for a partly sub-sampled pair, if the post spacing is every 4 pixels). In our experience with other types of planetary images, interactive editing can take as much as 50 hours per million posts.

<u>Final Product Generation:</u> This step may be divided into two components. The first is the generation and formatting of basic digital formats. It involves orthorectification of the image with the DEM, export of the DEM and orthoimage from SOCET SET to ISIS, and recording of these datasets on optical media (CD-R or DVD-R) with a final quality check. The second component is the generation of derived products such as contour and color-shaded-relief maps. This requires export of the data into ArcView for generation of the contours, shaded relief, and color-coded DEM as separate layers that must then be combined with one another or with the image. The coordinate grid and map scale are also generated in ArcView; final assembly and formatting of the maps is carried out in Adobe Illustrator. Finally, the Illustrator files must be archived to optical disk and the maps printed out on our large-format inkjet printer. We allocate 8 hours for finalization of the basic digital products, 40 hours for production of derived map products, and 2 hours for final quality control of all products. This work will be carried out by the senior photogrammetrists.

The total staff allocation is thus 129 hours for a full resolution stereopair and 91 hours for an 80% reduced resolution pair. Allowing for 8% of work time that is non-productive (i.e., 3.2 hours per week used for annual, sick, and administrative leave) the staff requirement is 0.067 workyear for a full pair and 0.048 workyear for a reduced resolution pair. To put these estimates in context, it is interesting to calculate that the USGS global DEM of Mars, which required over 10 years work to produce with the older, hardcopy stereomapping technology, contains about the same number of posts as three HiRISE DEMs. Considering that the global DEM was produced by interpolating relatively sparse contour data, it actually contains less real stereo-derived elevation information than a *single* HiRISE DEM.

7.4 Interface with Mars Geodesy/Cartography Working Group

Co-I Kirk will represent the HiRISE team on the Mars geodesy/cartography-working group, currently chaired by T. Duxbury, for the purpose of coordinating HiRISE observations that will contribute to improvements in the Mars geodetic control networks. Improved HiRISE boresight pointing (roll, pitch, and yaw) will be achieved by a systematic comparison of image geometry with Mars control networks and data from other MRO instruments. The wide swaths available from HiRISE imaging should be a significant aid in controlling the imaging to lower resolution data such as the Rand Corp. Control Network, USGS MDIM, and Mars Global Surveyor (MGS)/MOLA DEM products.

7.5 Science Analyses and Reporting

The science team is committed to the analysis of HiRISE data and dissemination of the results via scientific conferences and workshops and peer-reviewed publications. We are eager to contribute to specialized studies in support of future or ongoing MEP missions. Any collaboration will be welcome, especially joint studies with other MRO investigators. We expect to publish in journals such as Science, Nature, Geophysical Research Letters, JGR-Planets, Icarus, and others, including prompt contributions to special issues. Our science team budgets and schedules account for the associated time and expenses.

8 DATA ARCHIVE AND DISTRIBUTION PLAN

The MRO project requires the PI and investigation team to (1) maintain an updated dataset of the best version of data until meaningful changes in data calibration no longer occur, (2) release data in an appropriate manner for public access as soon as possible, (3) make data available to MRO project investigators, and (4) support the timely processing and distribution of data including their final deposition in the PDS.

The Data Archive Specialist and Web Archive Specialist carry out the data archive functions at HiROC. The Data Archive Specialist is responsible for (1) maintaining the HiCat system, (2) preparing hard media data distributions to Co-Is and the MRO special products database, (3) preparing and validating final product deliveries to the PDS, (4) participating in MRO DARWG meetings and coordinating archive activities with the PDS, and (5) maintaining database and system backups for HiROC. The Web Archive Specialist is responsible for (1) overseeing and managing the on-line data distribution system, (2) populating the on-line distribution system with the HiRISE data and ancillary data products, (3) monitoring HiWeb's usage, (4) assisting the preparation of web pages for special product release, and (5) assisting the Data Processing and Data Archive Specialists as needed.

HiWeb will provide web-based access to HiRISE products. The user-friendly interface will allow users to (1) search and locate images of interest based on geographic position, time, image ID, and other search criteria, (2) explore the selected images with basic image processing capabilities (including zoom, pan, and stretch), (3) download raw and processed images, (4) view images provided by the MRO context imager, (5) provide links to other MRO data sets, (6) view other Mars datasets.

8.1 Data Access Policy

HiRISE standard data products will be accessible to the HiRISE Science Team, MRO Investigators, and general science community (on a best effort basis) within weeks of acquisition. HiRISE products will be made available to all through the world wide web via HiWeb. Additionally, selected HiRISE standard data products will be made available to the MRO-developed "special products" database on a time schedule (probably within two weeks of data acquisition) agreed upon by the MRO project and the HiRISE team.

The HiRISE team will prepare captioned image data products for daily (five per week) press releases. These data will be available for public consumption through the HiRISE E/PO program. Images selected for special processing represent the most scientifically interesting observations acquired during the week.

8.2 Standard Data Products

HiRISE standard data products and delivery schedules to the PDS are identified in **table 8.2**.

Table 8.2 – HiRISE Standard Data Product Deliveries to the PDS

Product	NASA Level	Volume (Gb) based on 26Tb Mission	Hardmedia Delivery Date
EDR : Raw images (losslessly recompressed)	0	12,100	PSP+6
Binned Panchromatic RDR (losslessly compressed)	1C	24,400	PSP+12
Binned color RDR (losslessly compressed)	1C	3,200	PSP+12
RDR Standard Products delivered 6 months after end-of-mission			
Full-resolution panchromatic RDR	1C	30,300	EOM+6
Full-resolution merged color RDR	1C	32,000	EOM+6
2x2 binned stereo images	1C	1,900	EOM+6
Digital Elevation Models (DEMs)	3	1,000	EOM+6
Special Data Products			
EDR Ground Calibration (“safed”)	0	100	Launch + 6
EDR Cruise Calibration (“safed”)	0	100	PSP + 6

8.3 Data Distribution to the HiRISE Team

The primary method for access to data products by the HiRISE team will be through HiWeb using existing institutional Internet lines at the PI and Co-I institutions. For large volume data requests not practical for transfer through Internet resources, Co-Is will be able to order data products through HiWeb. HiROC operations staff will copy ordered data products to hard media for surface shipment to the Co-I institutions. Other groups will be expected to access HiRISE images only via HiWeb.

8.4 Data Distribution to MRO Project Investigators

MRO project investigators can access HiRISE data products through HiWeb using the same services and time frame available to the HiRISE team. Limited surface shipment of HiRISE products copied to hard media will also be supported. If desired by the MRO project, selected HiRISE products critical to project investigators will be delivered to the RSDS on a schedule to be determined by the MRO project and HiRISE team.

8.5 Public Access to HiRISE Data Products

An important component of the E/PO plan will be providing for the distribution of HiRISE images to the public. All users, including the public will be able to access all released HiRISE images through the public HiWeb site. The HiRISE team plans to release images to the website within weeks of image acquisition. The same map-based browser tool used to serve data from previous Mars missions will also identify the localities of available HiRISE images and DEMs. Clicking on the image outline will bring up the HiRISE image viewer that will display JPEG2000 versions of the images. Users will be able to pan across and zoom into the large, full-resolution HiRISE images. This will allow users to download only the portion of the image at the resolution that is of interest. Users will be able to download portions of a HiRISE image in a variety of popular image formats (tiff, jpeg, jpeg2000, gif, and PDS). An adaptive click-and-drag measuring tool will be available to allow users to measure feature sizes. Basic image processing adjustments (e.g. histogram display and equalization, manual contrast/brightness-stretching, zooming, cropping, and edge detection) will also be available. Combined with the HiWeb image viewer, these on-line tools obviate the need for most casual users to download the entire (very large) image in order to make simple adjustments needed to view them. This strategy should reduce demands on HiROC servers. Images served by HiWeb will reside on the UA servers throughout the active MRO mission. Ideally, mirror sites would be setup at Co-I institutions to reduce the demands on HiROC servers but this is not currently funded. After arrival at the PDS, the HiWeb links will be updated to pull data as needed from the PDS. In addition, the top-level HiRISE web site will feature a captioned 'image of the day'.

The HiRISE "People's Camera" philosophy calls for a best effort to provide public access to HiRISE images within weeks of image acquisition. The public can access HiRISE data products through HiWeb using the same services and time frame available to the HiRISE team. However, due to potential limitations on the bandwidth of Internet resources this service will be available on a "best effort" basis. The bandwidth available for HiRISE data distribution through institutional resources will be continually monitored. If public access to HiRISE products begins to restrict the access availability by HiRISE team members and MRO scientists then Internet bandwidths available to the general public will be reduced.

8.6 Data Distribution to the Planetary Data System

Data archive and distribution to the PDS will be coordinated through the MRO Data Archive Working Group (DARWG). DARWG (made up of representatives from the MRO project, science payload teams, and the PDS) provides the oversight for MRO data product preparation, acceptance, validation, and delivery to the archive facility. Co-I Eliason and the Data Archive Specialist will participate in the DARWG meetings.

Data product delivery to the PDS will be organized on appropriate high-density media acceptable to the PDS and the MRO project. The standard data products and delivery schedules are summarized in **table 8.2**. For EDR Data products the first delivery will occur six months after the start of PSP. Subsequent EDR deliveries occur at three month intervals (subject to agreements established by the DARWG). For Binned RDR Products (radiometrically corrected and map projected to a standard map project binned at least 2x2) the first delivery will occur 12 months after start of PSP with subsequent deliveries occurring at three month intervals. The Full-Resolution RDR products will be delivered six months after the end of PSP. The data products will be validated for compliance to PDS standards by applying PDS-developed validation software.

The format, organization, and contents of the data products delivered to the PDS are defined by the Software Interface Specifications (SIS) documents. Co-I Eliason will develop (1) a Data Product SIS defining the organization and contents of the standard data products, and (2) a Data Volume SIS describing the volume organization and ancillary data, software, and documentation that will accompany the data products.

8.6.1 HiRISE Data Node for the PDS

The HiROC facility may participate as a PDS HiRISE Data Node. The HiROC team will be part of the recompetition of the PDS Imaging Node in October 2003 whereby we will set forth a plan to act as a Data Node during MRO active operations. The success of our PDS HiRISE Data Node will be determined in April 2004 when the proposal contracts are awarded. The current EOP plan does not rely on the HiROC facility becoming a Data Node. Our baseline plan is to deliver hardmedia to the PDS Imaging Node according to the schedule outlined above.

9 SOFTWARE DEVELOPMENT PLAN

Development of the HiROC facility and supporting data analysis tools will result from a coordinated development effort among PI and Co-I institutions. The HiRISE team at the UA will be responsible for developing most of the systems and data management software elements that will operate at HiROC. The USGS group is responsible for the development of the ISIS image processing capabilities that (1) support the core analytical scientific data production pipeline requirements that support HiROC and (2) provide the science analysis and image processing package that will be used by the Co-Is at their home institutions. The Marsoweb group at Ames led by V. Gulick is responsible for the development of the HiWeb system. Additionally, we expect to develop HiPlan plug-in modules for use with MTT, perhaps integrated into HiPlan with help from the MTT programmers at ASU (a meeting to discuss this is planned for October 7, 2003). **Table 9.0** summarizes the software development tasks for each institution. A preliminary Work Breakdown Structure (WBS) and schedule for software development is itemized in **Appendix B**. **Table 2.1b** summarizes the total work commitments for the development of the HiROC, ISIS data analysis system, and HiWeb development.

HiROC Sub-System Functional Requirements Documents (FRD) and Software Interface Specifications (SIS) will be developed or revised during FY02-FY04. The FRD's detail the data processing methods for uplink and downlink data flow. The SIS's are used to detail the interface specifications needed for software and data products used by other institutions. HiROC MOS/GDS Peer Reviews and Operational Readiness Reviews will be conducted periodically to evaluate the status of the software implementation for HiROC. The HiRISE science team will be canvassed to evaluate the HiWeb and HiPlan software to ensure their requirements are met. Science team members will have the opportunity to test drive the ISIS data processing and analysis tools and provide feedback on problems and improvements with the software. HiROC capabilities will be tested during the Operational Readiness Tests planned by the project in FY04-06. The key milestones for the software development plan correspond to the pivotal mission events as shown in **table 12.0a**

For initial instrument calibration, the core elements of HiROC's software capability will be developed to basic levels of functionality sufficient to test and evaluate instrument operations. A prototype HiCat database system will be operational to gather calibration data and support the HiProc process management system. The HiProc pipeline mechanism will be used to orchestrate a preliminary HiDOg implementation for data delivery from the engineering facility (simulating RSDS delivery), data decompression using deFELICS, and EDRgen for generation of Level-0 PDS data product image files to be checked for correct instrument functioning. These tools will continue to be used throughout ATLO, with the addition of a prototype implementation of HiCommand, and from this experience they will be refined to best support the fundamental command uplink and science data downlink procedures. We are also relying on project-provided software such as SEQGEN and AMMOS query tools (see **table 4.0**) in ATLO.

Software tools will be in place by launch to support in-flight calibration tests and instrument checkout consistent with normal operations. HiCommand will be able to generate all HiRISE command blocks from PTF files and HiCat table entries. Engineering data gathering will be in place to ensure the necessary distribution and monitoring of this data stream. The HiDOg pipeline will be using FEI to directly access the MRO Raw Science Data Server (RSDS) for data delivery to HiROC and HiProc will be used for routine generation of EDR products. ISIS image processing capabilities will be in place to test out the instrument's geometric and radiometric calibration model using an initial implementation of the RDR generation pipelines. HiWeb's image suggestion selection function will be in place and using HiCat as its information repository. Following the successful launch, science team members, MRO investigators, and the science community will begin populating the image suggestion database.

By the start of the Primary Science Phase all software systems will be ready to generate all instrument commands from observation request specifications and process all science and engineering data streams from the instrument. Integration of HiPlan and HiWeb with HiCat will have been completed by MOI so that observation planning procedures can proceed. RDRgen HiProc pipelines based on ISIS procedures will have been implemented and tested to produce basic Level-1C products. A first implementation of HiVali will be able to validate EDR products and initiate RDRgen. HiSPICE will be ready to coordinate the delivery of SPICE files in support of RDRgen. HiReport will be able to generate status and summary reports for procedure pipelines. Test scenarios and fire-drills will have been run to ensure the reliability of the systems.

PDS data deliveries will begin after refinements to the radiometric and geometric camera model have resulted in RDRgen producing images that need no further adjustments to meet high quality Level-1C standards (see **table 8.2** for standard data products listing). Additional HiVali configurations will be in place for use by operators inspecting the results of automated processing. The HiArch procedures will have been implemented and tested to meet PDS standards.

9.1 Software Foundations

The key areas of software functionality needed to accomplish HiRISE are:

- Operating systems foundations and administration utilities
- Software development tools and runtime libraries
- Database services
- Scientific image processing capabilities
- Mission data access facilities
- Process management capabilities
- Observation planning tools
- Web site services
- High level planetary science analysis tools

The majority of the software functionality at HiROC will be provided by off-the-shelf Open Software and commercial products. Where specialized functionality is needed data management and analysis tools will be developed using leverage from existing software that has been identified as offering similar functionality that can be readily built upon or adapted to meet HiRISE requirements. HiRISE software will be developed using software engineering best practices. Runtime unit tests will be provided for ensuring the correct functioning of software procedures. Distribution packages for software suitable for installation at Co-I or other science analysis facilities will be made available. These packages will include Users Guides and public API documentation.

HiROC will use Unix operating systems for their breadth of facilities, depth of operational experience, and high levels of reliable performance. A key criteria is support for 64-bit operations, especially a file system with large (>4GB) file capability. Solaris 9 from Sun Microsystems (http://www.sun.com) will be used on platforms employing the SPARC architecture. GNU/Linux will be used on platforms employing x86 architectures; the specific kernel version and vendor distribution will be determined based on an evaluation of 64-bit and large file capabilities plus the completeness of the distribution and its support. OS-X from Apple (http://www.apple.com/software/) for Macintosh computers may be used on a limited basis in the HiROC facility primarily as inexpensive desktops for operators working with observation planning, database management, procedure monitoring and product validation Java-based tools as well as to provide general purpose desktops for office productivity purposes.

The software development tools will be standardized against a reference version of the language compiler and its runtime environment. For compiling C, C++ and FORTRAN source code the GNU Compiler Collection (gcc) version 3.2.2 from the Free Software Foundation (http://www.fsf.org/software/gcc/) is the baseline. For Java the Sun version 1.4.1 distribution (http://java.sun.com/) will be the baseline. GNU (http://www.fsf.org) make version 3.80 will be reference for software build Makefiles. External support libraries used in software implementations will also have their reference versions identified when the software is developed. These reference versions may be raised until launch at which point they will be frozen; after that point only bug and security patches may be applied to the OS and development tools. Specification of reference versions will be provided in software distribution packages. All source code and support files will be managed under the Concurrent Versions System (CVS; http://www.cvshome.org).

HiROC will use the MySQL database software from MySQL AB (http://www.mysql.com/) as the foundation on which to build HiCat. MySQL 4.0.13 is the current reference version, though this is expected to be raised. The UA group's experience using MySQL (for the MGS MOC database, amongst others) has proven it to be a reliable, high performance open system that avoids the complications and costs of commercial systems while meeting the requirements for HiCat. The MTT (built from the THEMIS JMARS targeting tool) observation planning tool also uses MySQL for its backend support, which should help ease the integration of the new HiPlan tool with the HiROC operating environment. The Java Database package developed at the Planetary Image Research Lab (PIRL, the home of the HiRISE UA group; http://pirlwww.lpl.arizona.edu/) offers simplified, abstract access to relational SQL databases (including MySQL). It is freely available, as part of the PIRL Java Packages (http://pirlwww.lpl.arizona.edu/software/PIRL_Java_Packages.html), to facilitate developing Java applications that intend to use information from HiCat or other databases. It has been used in the implementation of the Data_View application (http://pirlwww.lpl.arizona.edu/software/Data_View-beta.html), currently under development at PIRL, and in other contexts.

Scientific image processing capabilities will be provided by the Integrated Software for Imagers and Spectrometers (ISIS) from the Astrogeology Team of the USGS (http://wwwflag.wr.usgs.gov/USGSFlag/Data/software/software.html). The current reference version is 2.1, but a new version 3.0 is in development. ISIS has been used to support the image data processing needs of other spacecraft missions. The RDRgen pipelines will be built using ISIS procedures. ISIS offers a comprehensive set of software for processing, analyzing, and displaying spacecraft mission image data. Capabilities include data ingestion of PDS products, radiometric correction, geometric rectification, and photometric normalization. ISIS also has digital cartographic processing capabilities to perform C-smithing, registering images to a ground control network, map assembly, map projection, and image mosaicking. ISIS 3.0 is required to handle the very large image sizes expected from HiRISE. ISIS is freely distributed to the science community.

Access to instrument science data will be accomplished using the File Exchange Interface (FEI) provided by the Multi-mission Image Processing Laboratory (MIPL) at JPL (http://www-mipl.jpl.nasa.gov/). The current reference version is 3, with ongoing update deliveries. This client-server software is used to deliver files from the RSDS site in both push (asynchronous) and pull (synchronous) modes. The HiDOg pipeline is started by FEI when instrument observation metadata is pushed to HiROC, and FEI is used to pull the corresponding science data to HiROC. Access to the spacecraft engineering data stream is provided through the SOPC facility provided by JPL to the HiROC site. This computer system has a dedicated communication line to JPL and includes Data Monitor and Display (DMD) software to access the engineering data stream as it arrives on the communication link. The ENGdist/ENGmon procedures are expected to rely on the SOPC and its DMD software. The spacecraft and instrument location, orientation and ancillary information is contained in SPICE files obtained from the Navigation and Ancillary Information Facility (NAIF) of the PDS (http://pds.jpl.nasa.gov/naif.html) and may also be available at the RSDS. These files are made available from the NAIF as they are produced and updated and their contents will be interpreted using the NAIF SPICE Toolkit utilities. The HiSPICE implementation will access the NAIF distribution site (or RSDS) to obtain the latest SPICE files and use the SPICE Toolkit to confirm that the necessary information to process an observation is present.

The HiProc management capabilities will be provided by the Conductor package (http://pirlwww.lpl.arizona.edu/software/Conductor.html) developed at PIRL). Conductor offers reliable and consistent automated procedure pipeline operation against a queue of data source files with detailed procedure operation and status logging, error trapping and programmatic on-failure handling, and either foreground or background pipeline management. Conductor enables conflict free multi-processor operation for increased throughput and uninterrupted data processing even when a host system in a cluster goes down. Conductor uses a database (accessed using the PIRL Java Database package) as the repository for pipeline procedure definitions, dynamic resolution of command line variables, and source file queue lists and status recording. Conductor also uses the PIRL Java PVL (Parameter Value Language) package for configuration file management, including user-specified parameters for dynamic pipeline procedures definitions. The PVL package conforms to PDS specifications and will be used in conjunction with the Database package to move values between PDS file parameters and HiCat tables field entries. A C language API for managing the PVL of PDS files - which provides support for the PDS image display capabilities of the PIRL enhanced version of the xv program and is being used by the Cassini Mission and other projects - is also available from PIRL (http://pirlwww.lpl.arizona.edu/software/PPVL/). A set of C++ PVL classes is also pending release for use by the project's software development teams. Moving information between PDS files and HiCat fields is a capability that will be required in various HiProc procedure pipelines.

The HiPlan observation planning tools will build upon the MTT program from the THEMIS group of the Odyssey mission at Arizona State University (http://themis.asu.edu/). The THEMIS group has recast its JMARS observation planning tools (a Java application) as the Mars Targeting Tool (MTT) under an agreement with JPL. The MTT software has many of the sequence planning capabilities envisioned for HiPlan including use of a MySQL database backend, a graphical interface to plot orbit tracks and candidate targets on an image mosaic basemap of Mars, display of auxiliary images from other missions to support target assessment, and display of spacecraft and instrument operational constraints. MTT will be enhanced for HiPlan by incorporating modules for HiRISE instrument parameters and constraints, data volume, and using a database interface suitable for access to HiCat.

HiWeb (http://marsoweb.nas.nasa.gov/HiRISE) which is HiRISE's public web site will be developed by the Marsoweb group at Ames led by V. Gulick (ARC/SETI Inst.). Marsoweb (http://marsoweb.nas.nasa.gov/) is the MER resource center website for evaluating potential landing sites. It has many of the capabilities envisioned for HiWeb including an interactive graphical display of global maps of Mars, selection and display of image data sets from Mars missions, and image enhancement and analysis tools. These capabilities will be adapted for HiWeb by incorporating controlled access to the HiCat database and image file repository at HiROC.

Numerous high level planetary science analysis tools will be employed during the course of the HiRISE Mission; from calibration procedures where the flexibility of the commercial IDL (Interactive Data Language) from Research Systems Inc. (http://www.rsinc.com) is expected to be needed, to the production of digital elevation models (DEM) which will rely on the commercial digital photogrammetric software SOCET SET (Softcopy Exploitation Toolset) from BAE Systems (http://talisin.com/). While it is, of course, impossible to enumerate all of the high level science analysis tools that will be brought to bear to ensure the quality of the HiRISE data products, the use of IDL and SOCET SET have been identified as essential for determining the correct functioning of the instrument before flight and for producing the specialized data products to meet the science goals of the Mission.

Table 9.0 – Development Tasks for HiROC Subsystems

Subsystem	Description
UA Development Team	
HiCat	Database Cataloging System. The repository for all HiRISE observation specification information, instrument science metadata, data processing definitions, system event information, and ancillary data. In addition to the design, implementation and maintenance work associated with the database server software itself, software tools for monitoring and managing the database contents both interactively by an operator and programmatically by other software procedures will be developed.
HiProc	Procedures Pipeline Management. Uses procedure definitions and source file lists in HiCat to automate various task sequences such as HiCommand, HiDOg, EDRgen, RDRgen, etc. with detailed logging of all procedures. Operates in the HiROC multi-processing, parallel system environment to provide high throughput and high availability for the large data loads and fast turn-around times of the HiRISE mission. HiProc pipeline processing may be initiated automatically as a background batch job by a source file being placed on its ready list, or manually with interactive monitoring by user action.
HiReport	Procedures reporting. Examines HiProc pipelines and log files to generate status reports of data sets that are pending processing and those that have completed processing along with their completion status. Detailed and/or summary reports may be directed to a monitor console or sent to designated recipients.
HiCommand	Instrument command file generation and uplink. Uses observation specification information deposited into HiCat by HiPlan, and other Payload Target File sources, to generate Spacecraft Activity Sequence Files destined for spacecraft upload. Applies command validity constraint rules for verification of HiRISE image blocks employed by the Integrated Target List facility of the flight software. A HiProc pipeline initiated by a Targeting Specialist manages the SASF generation and delivery to JPL.
HiDOg	Data downlink organizer. A HiProc pipeline and support procedures to manage the receipt of instrument science data via FEI from the JPL RSDS. Science metadata is

	ingested into HiCat along with system event updates. HiProc options set in HiCat are used to control the acquisition of image data, verify it against the corresponding observation specification that had been used by HiCommand to produce the data, and organize it for the next stage of EDRgen processing.
deFELICS	FELICS data decompression. The SEAKR software applied to incoming instrument science data that has been compressed by FELICS hardware on the spacecraft. The SEAKR product will be modified by the UA HiRISE team to accommodate data gaps introduced during instrument to ground transmission.
EDRgen	EDR image file generation. Assembles pairs of channel science data for CCD into a standard level-0 PDS formatted image file.
ENGdist	Engineering data distribution. A HiProc pipeline and support procedures to continually collect in "near real-time" spacecraft and instrument engineering data arriving at the SOPC into HiCat and redistribute this data with low-latency to designated Ball engineering support team.
ENGmon	Engineering data monitor. A HiRISE specific DMD implementation to monitor data collected by ENGdist for alert conditions maintained in HiCat a table and/or configuration file. Alerts will be directed to a monitoring console, designated engineering teams and system event logs. Note: development contributions expected are from LMA and JPL.
HiVali	Data validation interface. A form oriented GUI, with an image display and manipulation tool, based on a rules-based configuration used by data validation operators to ensure that each data set has been visually checked and appropriate interpretive information gathered before the data set is passed on to the next stage of processing. Uses HiCat for the queue of data sets ready for validation, and the repository of information gathered. Data sets are passed on either to a HiProc pipeline ready list or a notice is sent to designated recipients of an unacceptable data set.
HiSPICE	SPICE information update. Ensures that the NAIF SPICE files necessary for processing a particular observation are available from the NAIF repository. A HiProc pipeline will be used to transfer the appropriate files to HiROC and apply any preprocessing relevant to their use by RDRgen procedures. Note: this will be an UA/USGS joint development effort.
RDRgen	RDR image files generation. HiProc pipelines employing ISIS routines to produce high level data products (Level-1C) conforming to PDS formatting standards. Pipelines will be implemented for each type of standard data product. Pipeline processing will be initiated by a HiVALI, or an authorized operator, entering an EDR or previous RDRgen data product filename on the appropriate ready list.
HiArch	PDS data validation and archiving. When EDRgen and RDRgen data products are successfully generated by a HiProc pipeline they will be automatically placed on another HiProc ready list to have PDS validation procedures applied to them to ensure that all products conform to PDS standards. Support procedures will be provided for the generation of ancillary files needed to meet PDS data set requirements. For writing PDS archiving additional HiProc pipelines will be used to ensure that all required components of a PDS dataset are properly organized and written to long term storage media.
HiPlan	HiRISE targeting planning. Enhancement to MTT for selecting HiRISE instrument parameters for processing by HiCommand.
USGS Development Team	
HiCal	Radiometric calibration procedure. Normalizes inter-detector sensitivity, subtracts Dark Current and bias, normalizes global instrument operating modes, and converts image data to I/F
HiColor	Color image generation. Co-registers blue-green and NIR filter to panchromatic imaging. This is process the combines existing ISIS capabilities.

HiGeom	Geometric correction procedure. Images are corrected for optical distortion and resampled to a standard cartographic map projection.
HiStitch	CCD swath stitching. Combines individual EDR images using approximate geometry to produce a single observation image in the original spacecraft viewing orientation.
HiJitter	Characterization of spacecraft jitter. Co-registration analysis of overlapping EDR image data for an observation identifies positional shifts from expected locations to create an updated SPICE CK file used by HiGeom.
HiPhot	Photometric normalization. Applies photometric model to calibrated HiRISE image taking into account incidence, emission, and phase angles, and corrects for atmospheric scattering. Photometric model [TBD].
PDS2ISIS ISIS2PDS	PDS-ISIS conversion. Converts images between ISIS and PDS labeling architectures.
HiBrow	Generate browse image for web application. HiWeb uses browse images to provide user with context of observation.
C-Smith	Pointing matrix update. Control images to ground network.
Ames Development Team	
HiWeb	Web information and services. Uses HiCat in coordination with a web site system to provide education and public outreach for the HiRISE mission, accept instrument observation requests, and offer the distribution of data products.

10 FACILITIES AND HARDWARE

HiROC facilities at the University of Arizona will be located at the former Campus Health Services building, 1 block west of Kuiper Space Sciences. HiRISE personnel will occupy the second floor and parts of the first floor of this building. The HiRISE data center computers will occupy the basement. University Facilities Management has come up with a $471K plan for renovating the basement to house the computers; this plan is presently under review by the University. They are also reviewing a proposal to replace rugs on the second floor and purchase furniture; cost estimate is $152K. The university has already approved an initial $146K for these efforts in 2003. **Table 10.0a** lists of highlights for the HiROC computer facilities. **Table 10.0b** summarizes the HiROC facilities space requirements of 4,900 sq ft.

Table 10.0a HiROC Computer room
400Sq. ft. enclosed room w/raised floor
40 KW natural gas backup generator
FM200 fire suppression system
2 cooling plants using facility chilled water
Backup refrigeration unit.

Table 10.0b HiROC Facility Space Needs in 2006-2009*

Space (Sq. ft.)	Space Requirements
900	Conference room -- lots of table/wall space needed for giant HiRISE images
3000	Office space for 24 people (PI, Co-I, HiROC mgr. 7 ops staff, 1 targeting specialist, 5 programmers, 2 system administrators, 2 administrative staff, 2 post-docs, 4 graduate students)
50	Secure room for SOPC
400	Computer banks, extra cooling and power

400	Visitor room
100	Large-format printer and supply room
300	Reception area
*The space allocation to HiRISE meets or exceeds these Requirements	

The HiROC facilities on the first and second floor of the former Health Services center will be publicly accessible during normal working hours. After hours, keyed entry to the building will be required. Keyed entry to the HiROC computer room in the basement and the SOPC room on the second floor will be required at all times. All persons that need access to HiROC will carry key cards that identify them. UA campus security personnel can request that identity key cards be shown after normal hours.

HiROC hardware capabilities need to be responsive to the significant data processing challenges offered by the experiment. During the two-year Primary Science Phase we expect to acquire approximately 10,000 images and a total downlink volume of 11-14 Tb. Creation of processed images will expand the data volume by 80-110 Tb or more, depending on S/C compression ratios. Datasets from other experiments (MOC, THEMIS, CRISM survey, CTX, etc.) will require an additional 10-20 Tb storage. HiROC and data analysis hardware requirements are summarized in **table 10.0c**. A hardware cost summary is provided in **table 13.1.**

Table 10.0c – HiRISE Hardware Requirements Summary
Secure a communications link to MRO OPS equivalent to two T-1 lines.
House Science Operations and Processing Computers (SOPC) at HiROC for communications with MRO OPS.
Provide a 300 Tb online storage capability.
Maintain a hardware processing capability to keep up with daily flow of image observations.
Provide a redundant hardware capability to reprocess data products with improved calibration methods.
Keep reliable backups of the complete HiRISE dataset.
Host targeting and sequence planning software.
Host the web-based HiWeb system for data distribution and candidate target selection.
Provide a capability to transfer large volumes of HiRISE images to the science team.
Develop security measures to protect HiROC from outside intrusion.
Enable a processing and data analysis capability at Science Team home institutions.

The MRO project will provide a secure communications link between the UA and MRO OPS. The line will have sufficient bandwidth to download daily volumes during the spacecraft's highest data rate transmission period. Additionally, the MRO project will install a SOPC at the UA and a backup SOPC at JPL. A summary of the HiRISE computational resources is shown in **figure 10.0**.

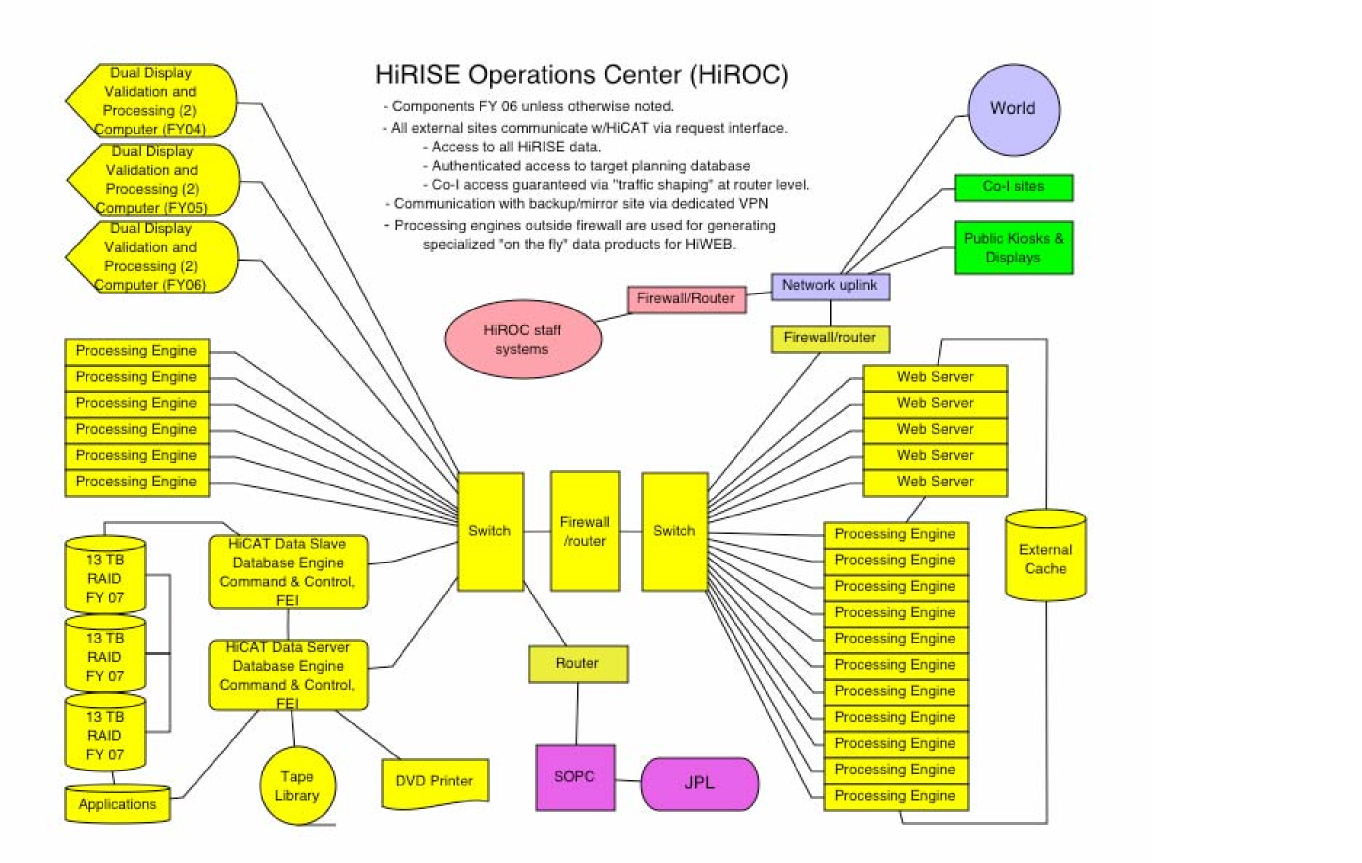

Figure 10.0 - Hardware configuration of the HiROC center and the other systems that support the computational needs of HiRISE. A firewall & router provides secure HiROC facilities (left side of figure). The secure elements of HiROC are the HiCat Data Servers and Database Engines, processing engines used to create our standard data products, large format display and visualization computers, and a network link to the MRO operations center through the SOPC. The HiROC elements outside the firewall include the HiWeb server, and processing engines for HiWeb's "on-the-fly" processing. Our offsite computer resources (upper right in figure) include the data analysis workstations located at each Co-I institution.

10.1 The HiROC Data Center

There are two major parts of the HiROC data and computer center. The first part of the data center contains the core processing, database, data storage, and display and validation computers. The second part of the data center includes Web servers, public data product processing engines, and cache disk storage for servicing HiWeb. The former is placed behind a secure firewall with outside access restricted to read access for the image database and images, plus read/write access for the "image request" database. The latter is maintained outside this firewall but still sitting behind a primary router that will be used for load balancing as well as security issues.

The database servers themselves will need to handle high loads of multiple requests to the data catalogs, plus these servers will be providing read and write access to the storage arrays, and will also be managing the HiRISE processing tables. Because of the many important functions of these servers, there will be two of them. One, a master will be able to write the catalogs and storage arrays, and the second, identically configured, will be able to work as a slave, responding to image and data requests, and will be ready to take over if the master fails. **Table 10.1a** describes the type of hardware that each database server will have.

Table 10.1a – HiROC Data Server Specifications
6 Processors: 2 GHz 64-bit processors
RAM: 12GB
Disk Storage: 1TB
Displays: none
Network: 1 Gb Ethernet, multi-homed
Storage: interface to high-capacity disk subsystems, tape library

The HiROC storage system will consist of high-speed on-line storage, and high-capacity near-line and off-line storage. In this context, the on-line storage is provided by redundant disk (RAID) arrays, and a robot tape library provides the near-line storage. The off-line storage is managed via a manual interface to the tape library. The largest cost to the HiROC will be the disk arrays. The arrays are managed by combining RAID 0 and RAID 5 controllers via a switched Fiber-channel storage-area (SAN) network. The ratio of storage devoted to RAID 0 and RAID 5 will depend on costs, data volume, and descope options. RAID 5 will be reserved for all critical data. Some of this critical data includes the target catalogs, command uploads, user databases, SPICE kernels, calibration data, etc. In decreasing order of priority are the latest downloads of spacecraft packets, compressed and uncompressed imaging data, press release data, level 0 EDR's, level 1C data products, ancillary datasets and level 3 standard data products. All RAID 5 and RAID 0 data will be regularly archived to the tape library and cycled into near-line and off-line storage. This will be happening continuously at the HiROC. Level 0 EDR's will be printed to hard media for shipment to the PDS. What the media might be is still under negotiation with the PDS, but a DVD printer/duplicator and allocations for enough DVD blanks to produce 4 complete level 0 EDR datasets are provided. At the present time, the PDS requires 3 complete archival datasets. The 4^{th} will be an archival copy for the HiROC.

Additional components of the HiROC include network switches for connection of all systems, a network firewall to separate the public and secure parts of the systems, plus a router to manage access to the HiWeb, allowances for cabling and software licensing, hardware maintenance money (increasing each year to allow for aging components and rising maintenance costs), and UPS's to isolate the systems from transient power grid problems. In addition, there are components of the HiROC provided by the University of Arizona, including the network uplink hardware, redundant cooling and backup power generation.

The HiROC data and web processing engines will be serving one of two purposes: (1) computational capabilities for HiROC image processing, and (2) processing for on-line access of HiRISE image products via HiWeb. The nature of the processing tasks of the HiROC and HiWeb lends itself well to the concept of an inexpensive distributed processing (Beowulf) environment. Jobs will be farmed out to these nodes for work, and data products retrieved once the work is completed. Since the Web and HiROC engines will be identically configured, they can be swapped to different duties in case anticipated needs don't match experienced demands. In addition, additional nodes can be acquired for little increase in cost. The processing nodes, shown in **table 10.1b** also will not need significant local disk storage.

Table 10.1b - Processing Engines
Processor: 3 GHz (64bit)

RAM: 4GB
Disk Storage: minimal
Displays: none
Network: 1 Gb Ethernet, multi-homed

The Web server computers will be servicing public requests to the HiRISE data. The Web server computers will be requesting data products from the HiCat through a dedicated software request interface, and farming image processing requests (thumbnails, tiling, pan and zoom) to the Web processing engines. The Web server computers, shown in **table 10.1c**, will need significant storage to cache publicly requested data to reduce redundancy of processing requests and to hold public release data products.

Table 10.1c - Web Servers
2 Processors: 3 GHz (64bit)
RAM: 2GB
Disk Storage: 1 TB
Displays: none
Network: 1 Gb Ethernet, multi-homed

Provisions have been made for two sites to display HiRISE images in a large-projection screen format. One site will be at the Lunar and Planetary Laboratory at the University of Arizona and the other will be at the Smithsonian Air and Space Museum in Washington, DC. The host institutions will absorb almost all of these costs. A minimal fraction of the total cost (estimated to be about $100K at the U of A) of these public displays is included to provide miscellaneous hardware and software support.

10.2 HiROC Network Security

HiROC will be separated into "public" and "private" sides. The public side contains the Web servers, processing engines for public data products, and on-line storage cache for public processed data. A router will monitor and control access to the public side of the system. All public web requests that can be honored (depending on bandwidth, data availability, and data processing constraints) will be serviced on the public side. The private side of HiROC houses the catalog server (HiCat), commanding and uplink systems, processing and data validation systems, and the HiRISE and ancillary dataset repositories. There will be no unencrypted access to the private side of HiROC, and a secondary router will tightly control access between the public and private sides. HiCat database requests from the public side will be forwarded through a special "request broker" system that will translate the requests into database commands understood by HiCat. HiCat will retrieve the requested information and forward it to the public side through the router and request broker. In the event of unauthorized penetration of the public side of HiROC there will be no increase in risk to the private side. If intrusion occurs, system upgrades and rebuilds of public-side servers will occur from secure backup, with patches applied to vulnerable services. Since there will be no privileged access from the public to private side, external penetration of the private side will be unlikely. Scanning and data integrity software will be employed on both sides of HiROC in order to detect unauthorized access.

10.3 Display/Development Computers

Our display/development computers will need large display capabilities plus enough processing power, RAM and internal disk storage as well as supporting the compile/test/debug cycle of the HiROC software components. Our nominal configuration for Display/Development computers is shown in **table 10.3**.

Estimated costs are based on a reasonable projection to FY 06. It's possible that the actual components could change as the display/development computers are purchased in different fiscal years.

Table 10.3 – Display / Development Computers
2 Processors: 3 GHz 64-bit processors
RAM: 2GB
Disk Storage: 400GB
2 Displays: 3+ megapixel
Network: 1 Gb Ethernet

10.4 Computer systems Based at Co-I Institutions

Computers, shown in **table 10.4** will be provided to co-investigators at their home institutions to provide for local processing of HiRISE data. There will be two computers at each of the 9 Co-I sites, one for the Co-I and one for a graduate student assistant or post-doctoral researcher, for 18 systems total. To ease setup and remote administration of these computers, they will be configured identically and shipped from the HiROC. All of these systems will be purchased in FY06.

Table 10.4 - Co-I Computer Systems
2 Processors: 3 GHz 64-bit processors
RAM: 2GB
Disk Storage: 1 TB (shared by the two systems)
Display: 4 Megapixel
Network: 1 Gb Ethernet
Removable hard drive bay and drives
DVD Recorder
High-resolution "B" format color inkjet printer.

11 TRAINING

The first experience the HiRISE team will have with operating the camera will occur during camera calibration and testing. Team members will become familiar with camera operational modes. The calibration of the camera will be an intense activity.

Once the camera has been delivered to ATLO the HiRISE team will participate in Mission System tests as directed by the project. The HiRISE team will develop test sequences for each test and test data will be reviewed.

The HiRISE team will prepare for their operational roles by having a series of training sessions at HiROC (probably in conjunction with team meetings) as software deliveries become available for "test drives". This training includes use of the ISIS data analysis package, SPICE tools, HiWeb, and the HiPlan targeting tool.

We expect to be involved in project Operational Readiness Tests before and after launch

12 SCHEDULES, DELIVERABLES, AND SERVICES

The HiRISE EOP schedule is centered on major mission milestones (Instrument Calibration, start of ATLO, launch, Mars Orbit Insertion, Transition Orbit, and hard-media delivery of data products to the PDS). **Table 12.0a** lists the dates *before* which each software system release is to be delivered. The detailed scheduling of each task and subtask is listed in the WBS shown in **Appendix B**.

12.1 HiROC Ground Data System Releases

HiROC GDS Release 0.1: Versions of HiCat, EDRgen, Conductor, HiProc, and HiCal will be available for instrument calibration activities at Ball providing the basic software tools to process, evaluate, and analyze the calibration data. These initial tools will allow efficient evaluation of the camera in all operating modes. The data analysis tools will include a mix of standalone IDL, ISIS, and other routines developed by the calibration team (an independent development effort).

HiROC GDS Release 0.2: For ATLO support in addition to the software tools developed for calibration we will have the ability to command HiRISE using a preliminary version of HiCommand and decompress the data stream with the DeFELICS program. This version of HiCommand will have a simple user interface to generate the camera commands, but will not be integrated with the more user-friendly HiPlan. Data retrieval procedures (HiDOg) from the JPL Raw Science Data Server will be functional and we will have the ability to automatically generate EDR products. We will also have the capability to monitor the instrument's health and performance with the ENGmon tool (HiRISE's implementation of the DMD tool).

HiROC GDS Release 0.3: For the Operational Readiness Test periods before launch, we will use improved versions of the software capabilities delivered in Release 0.2. During ATLO we will identify improvements that need to be made to the GDS sub-systems.

HiROC GDS Release 1.0: By launch we require the ability to command HiRISE for the calibration observations during cruise and retrieve and analyze the resulting data sets. To support this, HiCommand, HiDOg, HiProc (especially EDRgen, and preliminary versions of HiGeom and HiCal), HiCat, and related software/hardware elements will all be functional. We will be able to track the health and functionality of HiRISE and automatically retrieve data from the RSDS and deliver engineering data to Ball Aerospace for their instrument health monitoring activities. However, there is no requirement that the system be able to handle the volume of data that will be needed in Mars orbit. Launch will also provide a public event to kick-off E/PO activities including the ability of the public to suggest HiRISE targeting via HiWeb. The HiCat database will also be operational, allowing the calibration data and suggested images to be stored, searched, and accessed. Calibration data collected during cruise will be used to update the radiometric and geometric models for HiRISE. This will also provide the first data to test the jitter of the spacecraft during HiRISE imaging.

HiROC GDS Release 2.0: By Mars-Orbit-Insertion (MOI), we will have the tools to begin planning of the science sequences while in Mars orbit. This will be essential to support TAG planning. In order to achieve this, HiPlan will be brought to operational status, and HiWeb and HiCat will undergo additional development. Calibration files will continue to be updated.

HiROC GDS Release 2.1: At the beginning of the Transition orbit we will move into full operations. We will have fast user-friendly tested software for commanding the camera in all its modes, retrieving and processing the torrent of data in near real-time and orchestrating operations with the project. The automated archiving and the jitter correction software will enter the testing phase. HiCal and HiGeom will be fully updated using the initial PSP data in time for the best calibration to be used for the production of the first delivery of EDR and binned RDR products.

<u>HiROC GDS Releases 2.1 and 2.2</u>: Release 2.2 enables preparation of the EDR archives for delivery to the PDS and Release 2.3 enables the initial delivery of the binned RDR products to the PDS. Data will be processed and validated at the same pace that it is collected, requiring the fully operational versions of HiArchive. Regular deliveries will be made to the PDS at approximately 3-month intervals.

As noted in **table 12.0a,** HiRISE data will be released via HiWeb and delivered to the PDS at 3 distinct levels of processing (EDR, binned RDR, and full-resolution RDR products). EDR products will be released to the PDS at PSP entry +6 months, once the basic operation of the camera in Mars orbit is understood. As such, they will not be placed on the web until binned RDR products are ready for the web.

Products that require HiJitter will be delivered on hard-media to the PDS 6 months after the end of the primary mission. This includes full-resolution panchromatic and color images that have been geometrically and radiometrically calibrated, as well as digital elevation maps derived from stereo images. However, these products will be released over the web as soon as they are constructed. While some research into the nature of the point spread function (PSF) will be conducted, we do not consider PSF reconstruction to be within the scope of our plans.

12.2 Science Deliverables

Science deliverables will mostly be in the form of peer-reviewed publications and press releases that will be scheduled as the results warrant. However, two specific publications are already planned. The "Instrument and Experiment Description" paper or papers should be published shortly after launch and the "60-day Report" of our initial results is expected to be published by the time of the initial PDS delivery.

In addition to making all the HiRISE data available via the web, we will have specific web releases, such as the weekly image that was selected by a school group. The initial delivery of HiRISE data to the PDS will also be used as an E/PO event, including the first of annual "Educator Workshops" and release of curriculum materials including HiRISE materials. The curriculum support materials will also be made available via HiWeb. The production of binned and full-resolution RDR products that are available via the web, and the E/PO materials, are considered to be significant services that the HiRISE team will provide for the Mars science community and the general public.

Table 12.0a – Experiment Operations Schedule

Date	Description
	Mission Milestones
Mar/04	ATLO Readiness Review
Aug/04 – Mar/05	ATLO (for HiRISE Instrument) and Sequence Verification Tests
Jul/04 – Nov/05	Operational Readiness Test Period
Aug/05	Launch
Jan/06	Post Launch Operational Readiness Test

Mar/06	MOI
Sep/06	Transition Orbit
Nov/06	PSP
Dec/08	End of PSP
	HiRISE
	Review and Testing Milestones
Jan/03	HiROC Peer Review for Preliminary Design Review
Nov/03	HiROC Peer Review for CDR
Feb/04	MRO MOS/GDS CDR
May-Jun/04	Ground Calibration Period
	Software Delivery Milestones
Apr/04	HiROC GDS Release 0.1 - Instrument Ground Calibration Delivery
Jun/04	HiROC GDS Release 0.2 - ATLO Support Delivery
Mar/05	HiROC GDS Release 0.3 – ORT Period
Aug/05	HiROC GDS Release 1.0 - Launch Delivery
Mar/6	HiROC GDS Release 2.0 – MOI delivery
Sep/06	HiROC GDS Release 2.1 – Transition Orbit Delivery
Feb/07	HiROC GDS Release 2.2 – Support EDR Archive generation (PSP + 6 product release)
Apr/07	HiROC GDS Release 2.3 – Support binned RDR archive generation (PSP+12 product release)
	Science Milestones
Aug/05	HiRISE Instrument and Experiment (peer-reviewed papers)
Sep/05	Moon/Launch press release
Mar/06	Mars Approach press release
Dec/06	Begin weekly web releases (HiWeb)
Mar/07	"60-day Report" (peer-reviewed paper + LPSC presentations)
Jun/07	1st PDS Release
	E/PO Milestones
Jun/04	Formation of HiRISE Education Advisory Council (EAC)
Aug/05	HiWeb 1.0 (start requesting targets)
Mar/06	HiWeb 1.1 (web releases of cruise images, explanation of HiRISE)
Mar/06	Initial K-14 curriculum materials released (via HiWeb and other means)
Mar/06	Co-I's begin or increase work with students in schools, museums, planetariums
Dec/06	HiWeb 2.0 (Begin weekly E/PO web releases)
Jun/07	Release revised and bilingual curriculum materials (using more HiRISE products)
Jun/07	Start of annual "Educator Workshops" in conjunction with MEP E/PO
	Training Milestones
Apr/04	ATLO training (project tools including APGEN, SEQGEN, MTT)
Aug/05	ISIS Training and "test drive" #1
Mar/06	ISIS Training and "test drive" #2
Mar/06	HiPlan training to HiRISE team

Footnote for **Table 12.0a**: Version 0.5 is a functional version of the software that is still under development. Version 1.0 is the first fully operational version, but generally lacks the ability to operate at the full data rates needed for operations in the Primary Science Orbit. Version 2.0 will be able to deal with PSP operations, though some elements, such as calibration, will continue to be updated.

Table 12.0b lists the HiRISE deliverables to the project and internal deliverables to our team. Deliverables include our standard data products to the permanent archive facility, data product releases to MRO scientists and the general science community, science reports and publications, documentation requirements, Internet services, E/PO activities, software, and hardware. Delivery Dates are listed when appropriate.

Table 12.0b – HiRISE Deliverables and Services

Date	Deliverable
	Data Products to Permanent Archive Facility
Every 3 months	EDR (NASA Level-0) Products – Archive of raw spacecraft imaging submitted to the PDS.
Every 3 months	Binned RDR (NASA Level-1C) Products – Archive of derived imaging submitted to the PDS: spatially summed panchromatic imaging and color imaging with radiometric and geometric corrections.
End of PSP + 6 months	Full-Resolution RDR and Derived Products (NASA Level-3) – Archive of full spatial resolution panchromatic and color images; Digital Elevation Models submitted to the PDS.
Jun/07	Non-Standard Data Products – HiRISE calibration data submitted to PDS in “safed” form.
	E/PO Products and Services
5/week	Press release images with science captions released through MRO and HiRISE facilities.
Weekly	E/PO release
Ongoing	E/PO activities
	Data Product Release to MRO scientists and General Science Community
Weekly	NASA Level-0, Level-1C, and Level-3 HiRISE products released to science community through HiWeb, RSDS, or hard-media. Available within days or weeks of acquisition
	Science Reports
Periodically	Science reporting through NASA press conferences
Periodically	Science reporting via peer-reviewed publications, science conferences, and workshops
Aug/05	MRO publication describing science experiments
	Documentation
Sep/02	HiRISE Experiment Operations Plan Version 1.0
Oct/03	HiRISE Experiment Operations Plan Version 2.0
Mar/03	HiRISE Calibration Plan (internal document) Version 1.0
Aug/05	HiRISE Instrument Calibration Report
Feb/03	HiROC Functional Requirements Document (internal document)
	Internet Services
Aug/05	HiWeb – Candidate Target Definition System – HiRISE scientists, MRO scientists, and science community request HiRISE targets through internet resources
Dec/06	HiWeb – Data Product Distribution System – HiRISE scientists, MRO scientists,

	science community, and general public access HiRISE image data through internet resources.

13 MANAGEMENT AND COST PLAN

13.1 Cost Summary

Our Preliminary EOP (Sept 15, 2002) identified total expenses of $21.732M in Phase-E and requested 20% reserves. Actual funding is expected to be $20.86M and 13% reserves (email from R. Zurek, 2/3/03). Funding allocation by year (email from R. Zurek):

FY06: $6.46M, FY07: $6.222M, FY08: $5.25M, FY09: $2.93M

We decided to descope the backup operations center and mirror web site. Fortunately, the University of Arizona is expected to fund renovations to the HiROC computer center including non-water based fire suppression, raised floor, and increased security ($460K estimated cost), so the chances of needing a backup operations center are reduced. JPL (via DPI Hansen) will remain our backup for uplink. We think that a mirror web site at JPL (directly funded by JPL or PDS) will be needed to provide rapid access to HiRISE data by MEP scientists, for example to study candidate landing sites for MSL, but this has not been finalized. The backup operations center descope was expected to save $450K, but once the full implications were understood we added hardware to make our system more secure, reducing the cost savings to ~$350K.

On August 15, 2003 we had a meeting with Sue LaVoie and others from the PDS imaging node. We proposed that HiRISE serve as a PDS Data Node with significant cost-savings to both PDS and MRO from shared hardware and personnel. LaVoie agrees with our proposal and will include this in her PDS Imaging Node proposal. We are assuming that this will be approved for planning purposes, but this EOP lists only MRO funding.

Proposed support from PDS:

HiROC PDS Data Node Cost Summary

ACTIVITY	FY05		FY06		FY07		FY08		FY09		TOTALS
	FTE	$K	FTE	$K	FTE	$K	FTE	$K	FTE	$K	
SoftwareDevelopment & Operations Staff Costs (Burdened Costs)											
Data Processing Specialist	0.00	$0.0	0.50	$53.7	0.50	$56.4	0.50	$59.2	0.15	$18.6	$187.9
Software Development Engineer	0.80	$111.0	0.80	$116.5	0.40	$61.2	0.33	$53.0	0.00	$0.0	$341.6
Hardware Costs											
On-line File Server Storage		$0.0		$40.0		$30.0		$30.0		$0.0	$100.0
TOTALS:	**0.80**	**$111.0**	**1.30**	**$210.2**	**0.90**	**$147.5**	**0.83**	**$142.2**	**0.15**	**$18.6**	**$629.5**

FY05: $111K FY06: $210K FY07: $148K FY08: $142K FY09: $19K

This plan includes $100K total for hardware, which would reduce risk in our hardware plan, for example providing more space for reprocessing of the data. We have accommodated some of the funding shortfall (~$360K) by descoping the hardware (mostly RAID storage), reducing our ability to reprocess a large dataset, in part based on new (more favorable) cost estimates, but with some descope that we expect to recover via funding from PDS. Since we are putting our data products directly into PDS format, there is no need to store the dataset twice.

A number of other adjustments have been made to expected costs. Co-I Keszthelyi moved from UA to USGS. Co-I Eliason will move from USGS to LPL in April 2004. Software development has been accelerated in Phase D to support ground calibration, ATLO, and ORTs, changing (improving) the software development profile in Phase-E. The project selected JMARS from ASU/THEMIS as a starting point for MRO Target Tool (MTT); this helps us as we now plan to develop HiRISE plugins to JMARS/MTT for HiPlan, eliminating the need for a major new software development. Some new tasks have been added to our required effort, including improvements to the FELICS decompression code, needed to (1) speed execution, and (2) handle data gaps and other anomalies. We expect to meet a NASA mandate to release 5 captioned image products per week via the efforts of Co-Is and post-docs. There may be additional costs associated with delivering HiRISE data to other MRO experiment teams.

To summarize, we have accommodated the $872K funding cut via (1) descope of backup operations center ($350K), descope of computer hardware ($360K), moving some software development to Phase C/D (~$160K), plus there were a number of small increases and decreases. Reserves have been reduced from the 20% to 13%, so this plan now carries more risk. However, we do have viable descope options.

The revised HiRISE Phase-E cost estimates in real year dollars, including reserves, are summarized in **table 13.*1***. Identified are costs for all institutions, including science support, E/PO, and technical support for the development and operations of HiROC.

Table 13.1 - Phase-E Cost Summary

Organization	FY06-RY	FY07-RY	FY08-RY	FY09-RY	Total
Ball	$571.20	$269.28	$159.12	$106.08	$1,105.68
LPL-HiROC personnel	$1,815.57	$1,884.68	$1,513.92	$658.22	$5,872.39
HiROC (+ Co-I) hardware	$524.90	$156.50	$161.50	$57.70	$900.60
LPL (McEwen, Eliason, post-doc, admin.)	$765.99	$804.30	$844.50	$591.10	$3,005.89
USGS (Kesz, Kirk, Herken. ISIS, DEMs)	$1,203.00	$1,466.00	$919.00	$601.00	$4,189.00
Ames (Gulick)	$174.95	$241.66	$267.78	$187.12	$871.51
AMTI (Glen/HiWEB)	$192.90	$99.60	$83.00	$0.00	$375.50
Ames-EPO	$320.68	$263.63	$254.38	$92.84	$931.53
JPL (Hansen)	$175.00	$212.80	$215.60	$145.60	$749.00
U Col (Mellon)	$198.80	$247.19	$232.50	$170.73	$849.22
PSI (Weitz)	$188.61	$230.76	$243.68	$125.57	$788.61
Cornell (Squyres)	$205.39	$213.68	$216.80	$100.08	$735.96
CEPS (Grant)	$123.01	$129.93	$138.22	$93.96	$485.11
Total Year:	$6,460.00	$ 6,220.00	$ 5,250.00	$ 2,930.00	$ 20,860.00
MRO Funding (R. Zurek email, 2/3/03)	$6,460.00	$ 6,220.00	$ 5,250.00	$ 2,930.00	$ 20,860.00

The cost summary is further expanded in the appendices. **Appendix C** summarizes the software development and operations costs for the HiROC center. **Appendix D** provides information about the hardware costs to support HiROC and the Co-I science investigations at their home institutions. **Appendices E** and **F** provide a costs summary of the University of Arizona and USGS respectively. Phase-E cost plans for all other institutions (Ball, Ames/SETI, JPL, U. Colorado, PSI, Cornell, and CEPS) are unchanged from the HiRISE proposal, except for minor corrections to improve consistency in funding support for each Co-I.

13.2 Impacts on Cost Estimates

Our cost estimates are based on the acquisition of approximately 10,000 images, 9.1 Tb of downlink telemetry, 105 Tb (13 TB) of data products for PDS, and the ability to reprocess the entire dataset once.

We have kept Phase-E costs as low as possible via the following:

- Data archive resides at HiROC with web tools to analyze data, avoiding expensive data transfer to and storage at Co-I institutions.
- Estimates of hardware cost reductions over time.
- Simplicity of data products.
- Co-Is have standard hardware and software.
- Manage use of HiJitter (precision geometric correction), which requires research and development, by using it only for products with final delivery to PDS at EOM + 6 months

On 12/15/2002 R. Zurek asked us to consider possible cost impacts of an increase in the raw data for HiRISE in the PSP from 9.1 to 20 Tb. We presented 2 end-member options:

<u>Option 1 - Optimize Science</u>: Increase number of targets to 15,000 (50% increase) and increase image sizes ~33% via less binning, longer images, and more CCDs (up to power limit). Increase in # of off-nadir targets will depend on PSG negotiations. Planning includes full processing of extra data into standard data products. This plan could decrease the target planning work per observation via less tweaking to perfection to fit data volume limits and less chance of missing target. We would need a 50% increase in HiROC uplink and downlink staff, twice as many student validators, 25% increase in effort from science team members (including post-docs and students) to optimize targeting for science return, increase (~2x) on-line RAID storage, processing engines, media storage for PDS and backup. The capacity of the line between UA and JPL may need to increase (MRO project, not HiRISE cost), unless use of Internet II handles the extra load. The extra cost via this option is \$2.96 M (people) + \$0.60 M (hardware) = \$3.56 M

<u>Option 2 - No Cost Increase</u>: No increase in number of HiRISE observations (10,000). HiRISE products removed from on-line storage after 1 year (or rely on PDS funding to keep on line), so no increase in RAID storage. Take descopes totaling \$246K (see descope list). Impacts: targeting will not be as well optimized for science as in Options 1. Data access and reliability will be reduced. No increase in HiROC uplink and downlink staff or science team, but we still need to double the number of student validators. We will double the processing engines and media storage for PDS and backup. The capacity of the line between UA and JPL may need to increase (MRO cost), unless use of Internet II handles the extra load. Total extra cost to HiROC: \$208K (people) plus \$38K (hardware) = \$246K (the costs to be balanced by descopes).

13.3 Estimating Methodology

13.3.1 Cost Estimates for Software Development

Cost estimates for software development were based on an analysis of the work effort required to build the elements that make up HiROC and the ISIS data analysis package. The Work Breakdown Structure (WBS) shown in **Appendix B** itemizes our development time estimates for each software element. The WBS shows the development schedule and full-time work equivalents (FTE) for each fiscal year. The time estimates draw from our experience with other projects having similar requirements. Co-Is and software engineers developed these time estimates. The WBS items were assigned to the institutions responsible for software development (UA, USGS, and Ames). **Table 2.1b** shows the total development staffing requirements for each institution. The FTE estimates were then factored with the total costs for a senior software development engineer. The HiROC cost summary for staffing and development are shown in **Appendix C**. Our development staffing estimates were compared with the staffing for Mars Odyssey/THEMIS and shown to be comparable, in spite of the much larger (order of magnitude) data volume of HiRISE. HiROC staffing of 9 FTE in FY06 and FY07 is comparable to the 9 FTE to support THEMIS in the first year of active mission operations.

13.3.2 Cost Estimates for Operations Staffing

Cost estimates to support the HiROC ground operations were based on the data handling requirements that support the uplink and downlink data flow and systems administration support needed for the successful operation of the center. The operations staffing estimates assumes a one-shift schedule, 7 days/week, but with some flexible hours. Our operational staffing estimates for seven full-time staff members and two system administrators compare favorably with the staffing for the MRO Odyssey/THEMIS instrument operations. In the first year of operations, the THEMIS operations center employed eight full-time staff members and one system administrator. HiROC will need an assistant systems administrator to manage a system with a much larger data volume than THEMIS.

13.3.3 Cost Estimates for Hardware

HiROC hardware costs are based on average costs for particular pieces of hardware. Since computer hardware, for the most part, drops in cost over time, hardware estimates for most components are based on a cost projection to FY 06, when most of the HiROC hardware will need to be acquired. A summary of hardware costs is shown in **Appendix D**.

13.4 E/PO Costs

The E/PO costs of $931K for Phase-E are included in the totals listed in the Experiment Operations Plan. Total E/PO costs thru all phases represent about 2.0% of the HiRISE investigation's total proposed cost, which compares favorably with the E/PO funding guideline of 1-2%. The HiRISE E/PO plan is described in detail in the HiRISE proposal.

13.5 Phase-E Descope Options

The HiRISE team is planning a ground system that provides rapid access to processed images by the public and science community and first-rate science analysis. Our investigation will acquire the best possible data set, facilitate thorough preliminary science analyses both within and outside the HiRISE team, involve students and the public in a major way, and provide capabilities to support future Mars exploration. Phase-E descope options, listed in approximate order of priority in **table 13.5**, would reduce Phase-E costs by up to $4.47M. The savings would probably require the MEP to support future exploration or R&A programs to support science; duplication of effort could increase the ultimate costs to

NASA. Actual descopes could come from portions of several options rather than flowing from top to bottom of the list.

Table 13.5 - Phase-E Descope Options, Approx. Priority Order				
#	**Option (~Priority Order)**	**Consequences**	**Science, EPO, or MEP Loss; Loss of Deliverables or Services**	**$K Saving (TBR)**
1	Eliminate production of full-resolution Level1C products	Less RAID storage, image validation, PDS archival; drop 0.5 FTE data processing specialists. Users must process data from EDRs or use binned Level1c products	Increased costs to MEP for processing of full-resolution products. Many researchers would choose to analyze binned Level1c products and not realize information at full resolution. Loss of science results and reports.	$300K
2	Eliminate up to 25% of science team support	Eliminate up to 25% of salary and travel for PI, Co-Is, students and post-docs. Assuming they work 1/4 on operations and 3/4 on science analysis, this descope means elimination of 33% of team science analysis and special products.	Poorer observation planning (i.e., without supporting science results), less data analysis and local E/PO. Eliminate 33% of HiRISE science reporting and special products for press releases.	up to $1720K
3	Reduce E/PO to ~1% of total costs	Loss of 50% of the program (see text below descope ramifications on E/PO).	Loss of many E/PO activities, products, and services (see text).	$555K
4	Drop processing and archival of binned Level-1C products; software still available in ISIS	Process images through HiCal and HiStitch only for web release. Less RAID storage, image validation, PDS archival, drop 0.5 FTE data processing specialist.	Increased costs to MEP for special studies. Most researchers would reduce science effort rather than process a huge dataset themselves. Loss of Level-1C data products and science results.	$300K
5	Return fewer but larger images; ~5000 images total	Fewer images to plan and simpler data to process and archive; reduce staff by 1 FTE targeting specialist and 0.5 FTE assistant systems administrator. Reduced costs for PDS archival.	Fewer images acquired for science community outside MRO/MEP. No images targeted specially for E/PO. Fewer ride-along color images with CRISM. Less sampling leading to poorer targeting choices. Loss of science results and E/PO	$583K
6	Drop development of ISIS programs HiColor, HiPhot, C-SMITH, and HiJitter	No ability to produce well-registered color images and apply photometric corrections; DEMs reduced in precision to ~5 m. MEP will have to pay for these developments for landing site characterization.	Degraded color and photometric analysis, degraded E/PO products, DEMs not useful for meter-scale features. Loss of software deliveries and reduced science results.	$473K
7	Eliminate production of DEMs	DEM processing at USGS eliminated. Loss of experience that would benefit DEM production for characterization of landing sites.	No high-resolution topographic data for high-priority science. Loss of level 3 data products and the best quantitative science results from HiRISE.	$540K
			TOTAL:	**$4,471K**

13.5.1 Descope Options to E/PO Plans:

The descope option for reducing E/PO budget to 1% of project total, as shown in **table 13.5**, would result in a $555K cost savings to the project. **Table 13.5.1** summarizes the loss of E/PO programs in the event this option is exercised. The descope option reduces total E/PO effort based on original budget submitted in proposal to ~$569K.

Table 13.5.1 – Loss of E/PO Activities From Descope

E/PO Loss in Activities	$K Saving
Eliminate student and public filtering and image requests: eliminates NASA Quest participation	$120K
Reduce HiWeb E/PO website development by 1/3: eliminates student/public image request web site development. Impact: loss of a major selling point and unique aspect of HiRISE	$92K
Eliminate opportunities for public to participate in science analysis opportunities: Eliminate development of Clickworkers' modules: Impact: removes opportunity for direct public participation in the science they pay for; loss of another key selling point and unique aspect of HiRISE E/PO	$123K
Eliminate travel for E/PO Coordinator and travel by EAC members to HiRISE Team meetings and E/PO meetings. Would eliminate face to face meetings with HiRISE team members; would require all contact to be done via telecon and email. Impact: No opportunities for E/PO members to meet with each other, with science team or to learn directly about the mission from the team.	$31K
Eliminate Educator Workshops. Eliminate ASU K-12 E/PO participation. Impact: Eliminates a key E/PO partner and core traditional E/PO activity	$20K
Eliminate publication of HiRISE curriculum materials and new hands on activities in popular educator magazine that reaches 8000+ pre-college educators. Impact: Eliminates Space Place and the International technology Education's (ITEA) *Technology Teacher* magazine participation and a traditional E/PO activity. Impact: Reduces distribution of HiRISE curriculum materials and activities to posting on HiWeb E/PO website only. Only computer savvy educators who know where to look on the web will have access to HiRISE E/PO materials.	$12K
Reduce E/PO Coordinator activities by 1/4: (1) Reduce development of curriculum materials and lesson plans, (2) Reduce Northern California local E/PO efforts, (3) No Educator workshops organized, (4) Reduce collaborations with outside E/PO partners.	$57K
Proportional reduction in overhead:	$100K
TOTAL SAVINGS:	**$555 K**

13.5.2 Upscope Options.

There is one small and one potentially large upscope. The relatively small upscope would be to develop a new program "HiHeight" that would allow a scientist to extract the elevation change between two points on a stereo pair. We do not plan to produce DEMs for many stereo pairs, but this simple program would enable many science studies on stereo pairs without full DEMs. Others will certainly to this because it is a relatively simple effort with a large science pay off.

The potentially large upscope is PSF deconvolution to sharpen HiRISE images. The intrinsic Point Spread Function (PSF) of HiRISE will be excellent, less than two pixels full width at half max of the PSF. However, S/C jitter and yaw errors will broaden the PSF by an amount that will vary over time, and differ in the cross-track and down-track directions. From the CCD overlap imaging and analysis in HiJitter, we can model how the PSF is changing, and use this model to sharpen the images. This effort could be substantial both in terms of people time and computer processing. Noise is amplified by the PSF sharpening unless carefully characterized. We cannot scope this effort until in-flight jitter calibrations, including images of Mars and characterization of noise, are available. It is possible that jitter smear will often compromise the Level 1 science objective to resolve 1-meter scale objects.

Appendix A - Two days in the Life of HiRISE

We assume a low data rate day with two 12 Gb downlink opportunities, of which HiRISE receives 35% (2.8 Gb X band, 1.4 Gb Ka band). Times and rates for transfer from HiRISE raw SSR partition to framed space is approximate because it depends on the other processes the spacecraft CPU must perform. Raw partition is assumed to be 28 Gbits; framed space is 24 Gbits for Ka band and 48 Gbits for X band. We assume that HiRISE gets to use 35% of the framed space in each case (16.8 Gbits for X band, 8.4 Gbits for Ka). Transfer of data from the raw to the framed space is assumed to take place at a net rate of 7.5 Mb/s.

Event	Time (HH:MM)	HiRISE Raw Partition [Gbits]	HiRISE X-band Framed [Gbits]	HiRISE Ka-band Framed [Gbits]
Start of Sol 1				
Begin roll to acquire image 1	0:00	0.00	0.00	0.00
Start Acquire Image 1 (1147 Mpixels, potential landing site, ROTO, coordinate w/CTX and CRISM)	0:07	0.00	0.00	0.00
End Transfer Image 1	0:14	5.52	0.00	0.00
Start Packetize Image 1	0:14	5.52	0.00	0.00
End roll back to Nadir	0:15	5.07	0.45	0.00
Start Acquire Image 2 (348 Mpixels, landslide deposit, nadir, stand-alone)	0:22	1.92	3.60	0.00
End Transfer Image 2	0:24	2.73	4.05	0.00
End Packetize Image 1	0:26	1.71	5.52	0.00
Start Packetize Image 2	2:00	1.71	5.52	0.00
End Packetize Image 2	2:04	0.00	5.52	1.71
Start Downlink Pass 1	3:05	0.00	5.52	1.71
End Downlink Pass 1	3:55	0.00	2.72	0.31
Begin roll to acquire image 3	6:05	0.00	2.72	0.31
Start Acquire Image 3 (348 Mpixels, supervised high school project, ROTO, coordinate w/CTX)	6:12	0.00	2.72	0.31
End Transfer Image 3	6:14	1.71	2.72	0.31
End Roll back to nadir	6:20	1.71	2.72	0.31
Begin roll to acquire image 4	6:23	1.71	2.72	0.31
Start Acquire Image 4 (348 Mpixels, possible hydrothermal alteration, ROTO, coordinate w/CTX, CRISM)	6:34	1.71	2.72	0.31
End Transfer Image 4	6:32	3.42	2.72	0.31
End roll back to nadir	6:38	3.42	2.72	0.31
Start Packetize Image 3	8:00	2.80	2.72	0.31
End Packetize Image 3	8:04	1.71	4.43	0.31
Start Packetize Image 4	8:04	1.71	4.43	0.31
Start Acquire Image 5 (128 Mpixels, track changes in the polar deposits, nadir, stand-alone observation)	8:07	0.36	5.78	0.31
End Transfer Image 5	8:08	0.63	6.14	0.31
End Packetize Image 4	8:08	0.63	6.14	0.31
Start Acquire Image 6 (128 Mpixels, degraded rampart craters, nadir, coordinate w/CTX)	8:10	0.63	6.14	0.31
End Transfer Image 6	8:11	1.26	6.14	0.31
Start Packetize Image 5	9:00	1.26	6.14	0.31

End Packetize Image 5	9:02	0.63	6.14	0.94
Start Packetize Image 6	9:02	0.63	6.14	0.94
End Packetize Image 6	9:04	0.00	6.14	1.57
Start Acquire Image 7 (82 Mpixels, public image request, nadir, coordinate w/CTX)	10:11	0.00	6.14	1.57
End Transfer Image 7	10:12	0.42	6.14	1.57
Start Packetize Image 7	11:05	0.42	6.14	1.57
End Packetize Image 7	11:06	0.00	6.14	1.99
Start Acquire Image 8 (6 Mpixels, sample of CRISM observation, nadir, ride-along)	12:43	0.00	6.14	1.99
End Transfer Image 8	12:44	0.03	6.14	1.99
Start Acquire Image 9 (64 Mpixels, sample of unknown knobs, nadir, coordinate w/CTX)	12:55	0.03	6.14	1.99
End Transfer Image 9	12:55	0.37	6.14	1.99
Start Packetize Image 8	13:15	0.37	6.14	1.99
End Packetize Image 8	13:16	0.34	6.17	1.99
Start Packetize Image 9	13:16	0.34	6.17	1.99
End Packetize Image 9	13:17	0.00	6.17	2.33
Start Downlink Pass 2	15:05	0.00	6.17	2.33
End Downlink Pass 2	15:55	0.00	3.37	0.93
Start Acquire Image 10 (128 Mpixels, gullies, nadir, stand-alone)	16:12	0.00	3.37	0.93
End Transfer Image 10	16:13	0.63	3.37	0.93
Start Acquire Image 11 (128 Mpixels, fluvial channels, nadir, coordinate w/CTX)	16:14	0.63	3.37	0.93
End Transfer Image 11	16:15	1.26	3.37	0.93
Start Acquire Image 12 (64 Mpixels, lava flows, nadir, stand-alone)	16:30	1.26	3.37	0.93
End Transfer Image 12	16:31	1.60	3.37	0.93
Start Packetize Image 10	17:05	1.60	3.37	0.93
End Packetize Image10	17:07	0.97	3.37	1.56
Start Packetize Image 11	17:07	0.97	3.37	1.56
End Packetize Image 11	17:09	0.34	4.00	1.56
Start Packetize Image 12	17:09	0.34	4.00	1.56
End Packetize Image12	17:10	0.00	4.00	1.90
Begin roll to acquire image 13	18:08	0.00	4.00	1.90
Start Acquire Image 13 (348 Mpixels, possible source for floods, ROTO, coordinate w/CTX)	18:15	0.00	4.00	1.90
End Transfer Image 13	18:17	1.71	4.00	1.90
End roll back to nadir	18:23	1.71	4.00	1.90
Start Acquire Image 14 (128 Mpixels, active dune field, nadir, ride-along)	18:25	1.71	4.00	1.90
End Transfer Image 14	18:26	2.34	4.00	1.90
Start Packetize Image 13	19:00	2.34	4.00	1.90
End Packetize Image 13	19:04	0.63	5.71	1.90
Start Packetize Image 14	19:15	0.63	5.71	1.90
End Packetize Image 14	19:16	0.00	5.71	2.53
Start Acquire Image 15 (348 Mpixels, layered deposits in a canyon, nadir, coordinate w/CTX)	20:22	0.00	5.71	2.53
End Transfer Image 15	20:24	1.71	5.71	2.53
Start Packetize Image 15	21:05	1.71	5.71	2.53
End Packetize Image 15	21:12	0.00	7.42	2.53

Start Acquire Image 16 (128 megapixels, dust deposits, nadir, ride-along)	22:10	0.00	7.42	2.53
End Transfer Image 16	22:11	0.63	7.42	2.53
Start Packetize Image 16	23:05	0.63	7.42	2.53
End Packetize Image 16	23:08	0.00	7.42	3.16
START OF SOL 2 End Sol/Day 1, Start of Sol/Day 2	0:00	0.00	7.42	3.16
Start Downlink Pass 1	3:05	0.00	7.42	3.16
End Downlink Pass 2	3:55	0.00	4.62	1.76
Begin roll to acquire image 17	6:10	0.00	4.62	1.76
Start Acquire Image 17 (348 Mpixels, layered deposits in canyon walls, ROTO, coordinated w/CTX, CRISM)	6:17	0.00	4.62	1.76
End Transfer Image 17	6:19	1.71	4.62	1.76
End roll back to nadir	6:25	1.71	4.62	1.76
Start Packetize Image 17	7:00	1.71	4.62	1.76
End Packetize Image17	7:07	0.00	6.33	1.76
Start Acquire Image 18 (128 Mpixels, crater chains, nadir, ride-along)	8:12	0.00	6.33	1.76
End Transfer Image 18	8:13	0.63	6.33	1.76
Start Acquire Image 19 (348 Mpixels, fluvial erosion features, nadir, coordinated w/CTX)	8:20	0.63	6.33	1.76
End Transfer Image 19	8:22	2.34	6.33	1.76
Start Acquire Image 20 (82 Mpixels, public request, nadir coordinated w/CTX)	10:15	2.34	6.33	1.76
End Transfer Image 20	10:16	2.76	6.33	1.76
Start Acquire Image 21 (128 Mpixels, sample outwash plains, nadir, stand-alone)	10:20	2.76	6.33	1.76
End Transfer Image 21	10:21	3.39	6.33	1.76
Start Packetize Image 18	11:00	3.39	6.33	1.76
End Packetize Image 18	11:03	2.76	6.33	2.39
Start Packetize Image 19	11:03	2.76	6.33	2.39
End Packetize Image19	11:10	1.05	8.04	2.39
Start Packetize Image 20	11:10	1.05	8.04	2.39
End Packetize Image 20	11:13	0.63	8.04	2.81
Start Packetize Image 21	11:13	0.63	8.04	2.81
End Packetize Image 21	11:15	0.00	8.67	2.81
Start Acquire Image 22 (6 Mpixels, sample terra incognita, nadir, ride-along)	12:12	0.00	8.67	2.81
End Transfer Image 22	12:13	0.03	8.67	2.81
Start Acquire Image 23 (64 Mpixels, margin of possible rock glacier, nadir, coordinated w/CTX)	12:30	0.03	8.67	2.81
End Transfer Image 23	12:31	0.37	8.67	2.81
Start Packetize Image 22	13:00	0.37	8.67	2.81
End Packetize Image 22	13:01	0.34	8.67	2.84
Start Packetize Image 23	13:01	0.34	8.67	2.84
End Packetize Image 23	13:02	0.00	9.01	2.84
Start Downlink Pass 2	15:05	0.00	9.01	2.84
End Downlink Pass 2	15:55	0.00	6.21	1.44
End of Sol2	24:00	0.00	6.21	1.44

Appendix B – Work Breakdown Structure

WBS Item	Description	FY03	FY04	FY05	FY06	FY07	FY08	FY09	Tot
		Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	Q1 Q2 Q3 Q4	
		WK YEARS	WK YEARS	WK YEARS	WK YEARS	WK YEARS	WK YEARS	WK YEARS	WK YEARS

Mission Ops. Dev. **HiROC Development**

HiCat	HiRISE Catalog System	0.25	0.50	0.50	0.70	0.33	0.33	0.05	2.67
HiWeb	Candidate Target Def. and Data Dist.	0.00	0.33	0.50	0.76	0.38	0.30	0.00	2.27
HiMirror	Automated Mirror Site Data Transfer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conductor	Master Control - Orchestrate HiROC Ops	0.25	0.25	0.10	0.10	0.10	0.10	0.00	0.90
HiPlan	Develop Observation Sequences	0.00	0.00	0.50	1.00	0.75	0.35	0.05	2.65
HiCommand	Translate HiPLAN seq. to commands	0.00	0.30	0.20	0.70	0.26	0.25	0.05	1.76
HiDOg	Downlink Organizer	0.13	0.40	0.20	0.30	0.46	0.27	0.06	1.81
HiArchive	Procedures of PDS Archive Delivery	0.00	0.00	0.00	0.30	0.60	0.50	0.50	1.90
HiReport	Procedures and MOS Reporting	0.00	0.00	0.00	0.50	0.30	0.00	0.00	0.80
ENGdist	Destribute engineering data to Ball	0.00	0.20	0.00	0.40	0.10	0.00	0.00	0.70
ENGMon	Enigneering Monitor (DMD implentation)	0.00	0.10	0.00	0.10	0.10	0.00	0.00	0.30
HiVali	Data Validation Interface	0.00	0.00	0.00	0.50	0.30	0.00	0.00	0.80

Image Processing **Automated Image Processing**

HiProc	Auto Level-1C & Browse Production	0.13	0.20	0.20	0.50	0.45	0.26	0.05	1.79
EDRGEN	EDR Generator	0.00	0.25	0.25	0.70	0.30	0.13	0.05	1.68
DeFELICS	FELICS Decompression Software	0.00	0.30	0.30	0.40	0.10	0.00	0.00	1.10
RDRgen	RDR Pipeline Processing	0.00	0.00	0.25	0.80	0.93	0.13	0.00	2.11
HiSPICE	ISIS/SPICE integration	0.00	0.00	0.00	0.31	0.20	0.00	0.00	0.51
HiCal	Radiometric calibration to I/F	0.00	0.20	0.22	0.50	0.30	0.05	0.05	1.32
CTXCAL	Radiometric calibration ofr CTX	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HiColor	Merge Color Observation	0.00	0.00	0.11	0.10	0.00	0.00	0.00	0.21
HiGeom	Geometric transform to Level-1C	0.00	0.30	0.67	1.00	0.50	0.05	0.05	2.57
HiJitter	Jitter Analysis with DCA overlap	0.00	0.00	0.00	0.60	1.00	0.34	0.30	2.24
CTXGEOM	Geo transform CTX images to Level-1C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HiPhot	Photometric normalization	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.20
ISIS2PDS	Convert level-1C to PDS format	0.00	0.00	0.00	0.10	0.20	0.00	0.00	0.30
PDS2ISIS	Convert PDS to ISIS format	0.00	0.30	0.00	0.10	0.00	0.00	0.00	0.40
HiStitch	Stitch CCDs into single image	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10
HiBROW	Prepare browse images for HiWEB	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10
C-Smith	Control HiRISE Images to grnd. control	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.40
ISIS2IDL	ISIS/IDL Interface Routines	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.20
ISIS - Programs	Test & adapt ISIS programs to HiRISE	0.00	0.00	0.00	0.15	0.26	0.05	0.05	0.51
ISIS-MIRROR	Automatic ISIS update to Science Teams	0.00	0.00	0.00	0.15	0.30	0.05	0.05	0.55

Special Products **Special Processing for Science Analysis**

Anaglyph Dev.	Red-blue 3D viewing								
DEM Software	ISIS & SOCET SET HiRISE Adaptation	0.00	0.00	0.00	0.13	0.15	0.00	0.00	0.28
Flyover Movies	3D projections with zoom/flyover								
Walk-in-Park Sim.	Movies of walk in the park								
Shaded Relief	Shaded-relief created from DEMs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Change Detection	Co-Registration and stack MOC & HiRISE								
Composition Imgs.	Hi-res maps of compositional units								

UA Development	0.75	2.50	2.50	7.00	5.08	2.32	0.81	20.96
AMES Development	0.00	0.33	0.50	0.76	0.38	0.30	0.00	2.27
USGS Development	0.00	1.00	1.00	3.34	3.51	0.54	0.50	9.89
Minimal dev./ commercial purchase/ grad student dev.								

Appendix C - HiROC Staffing Cost Summary

Appendix C provides the staffing costs associated with the development and operations of HiROC. The costs include the development to ISIS science analysis package and the HiWeb catalog system. Costs for staffing levels shown in **Table 2.4** are provided here. Costs included support from the UA, USGS, and Ames. Costs include benefits and overhead.

HiROC STAFFING COST SUMMARY					
ACTIVITY	**FY06**	**FY07**	**FY08**	**FY09**	**TOTALS**
HiROC Operations Staff Costs					
HiROC Manager (in LPL Science Budget)	-	-	-	-	-
HiROC Senior System Administrator	$152.9	$160.6	$168.6	$88.5	$570.6
HiROC System Administrator	$107.4	$112.7	$118.4	$37.3	$375.8
Uplink					
Targeting Specialist #1 (lead)	$152.9	$160.6	$168.6	$88.5	$570.6
Targeting Specialist #2	$41.9	$112.7	$118.4	$37.3	$310.3
Targeting Specialist #3	$20.4	$112.7	$118.4	$37.3	$288.8
Downlink					
Data Processing Specialist #1	$107.4	$112.7	$118.4	$62.2	$400.7
Data Processing Specialist #2	$20.4	$112.7	$118.4	$62.2	$313.7
Data Archive Specialist	$107.4	$112.7	$118.4	$62.2	$400.7
Web Archive Specialist	$107.4	$112.7	$118.4	$62.2	$400.7
UA Student Validators (1/2 time employees)	$34.4	$72.2	$75.8	$39.8	$222.3
Software Development Costs					
Totals for UA Development	$1,070.5	$814.9	$390.3	$143.0	$2,815.8
Totals for AMES Development	$192.9	$99.6	$83.0	$0.0	$571.6
Totals for USGS Development	$691.0	$710.0	$184.0	$111.0	$1,961.7
Staffing Costs All Instituions (Totals of above)					
Totals for all UA technical staffing	$1,815.5	$1,884.7	$1,513.6	$658.2	$5,872.1
Totals for all AMES technical staffing	$192.9	$99.6	$83.0	$0.0	$571.6
Totals for all USGS Staffing	$691.0	$710.0	$184.0	$111.0	$1,961.7
HIROC OPS AND DEVELOPMENT TOTAL:	$2,699.4	$2,694.3	$1,780.6	$769.2	$7,943.6

Appendix D - Hardware Budget Summary

Appendix D summarizes the hardware costs necessary to build HiROC, and the Co-I science workstations. Some Co-Is require additional hardware beyond the base systems described in **section 10**. In these cases the hardware requirements are provided for in the individual Co-I budgets.

PHASE C/D - HARDWARE COSTS

Components	Per-unit cost, $K	FY04	FY05
U/A Dev/Validation Computers			
Dev/Validation computers	$4.90	2	2
Calibration/ATLO			
Calibration data server	$10.00	1	0
Hardware RAID (per TB)	$5.00	1	0
Calibration data processing engine	$2.00	1	0
IDL License	$1.50	1	0
Windows client	$1.00	1	0
Co-I at Institution Systems			
Co-I computer hardware	$6.70	0	0
Co-I B-format printer	$1.00	0	0
Co-I printer media	$0.40	0	0
Co-I DVD's (packs of 50)	$0.03	0	0
HiROC Data Center			
Data processing engines	$2.00	0	0
Web Processing engines	$2.00	0	0
Web server computers	$3.00	0	0
Network switch	$1.50	1	0
Network router	$2.00	1	0
UPS ($1 per VA)	$5.00	0	0
Fibre switch	$3.00	0	0
Hardware RAID (per TB)	$10.00	0	0
Workgroup RAID (per 100GB)	$1.00	1	1
Database server	$40.00	0	0
LTO drive	$1.00	1	0
Workgroup server	$8.00	1	0
Fibre cabling	$0.10	0	0
S/W licensing	$5.00	0	0
LTO tape libray	$15.00	0	0
DVD printer/duplicator	$5.00	0	0
Public display hardware	$10.00	0	0
Large format roll-feed printer	$10.00	0	0
Desktop systems	$3.00	6	2
Color printer	$2.50	1	0
B/W printer	$1.50	1	0
HiROC Consumables			
DVD blanks (packs of 250)	$0.15	0	0
200GB LTO tapes (packs of 12)	$0.80	1	1
Misc printing materials	$1.00	1	1
Hardware Maintenance	$5.00	0	1
Yearly Totals		$66.6	$23.6

PHASE E - HAREWARE COSTS

Components	Per-unit cost, $K	FY06	FY07	FY08	FY09
U/A Dev/Validation Computers					
Dev/Validation computers	$4.90	2	0	0	0
Calibration/ATLO					
Calibration data server	$10.00	0	0	0	0
Hardware RAID (per TB)	$5.00	0	0	0	0
Calibration data processing engine	$2.00	0	0	0	0
IDL License	$2.00	0	0	0	0
Windows client	$1.00	0	0	0	0
Co-I at Institution Systems					
Co-I computer hardware	$6.70	18	0	0	0
Co-I B-format printer	$1.00	9	0	0	0
Co-I printer media	$0.40	2	2	2	2
Co-I DVD's (packs of 50)	$0.03	9	9	9	9
HiROC Data Center					
Data processing engines	$2.00	6	0	0	0
Web Processing engines	$2.00	11	0	0	0
Web server computers	$3.00	5	0	0	0
Network switch	$1.50	2	0	0	0
Network router	$2.00	4	0	0	0
UPS ($1 per VA)	$5.00	3	1	1	0
Fibre switch	$3.00	1	1	1	0
Hardware RAID (per TB)	$15.00	8	8	8	0
Database server	$40.00	2	0	0	0
Fibre cabling	$0.10	4	4	4	0
S/W licensing	$5.00	2	1	1	1
LTO tape libray	$15.00	1	0	0	0
DVD printer/duplicator	$5.00	1	0	0	0
Public display hardware	$10.00	1	0	0	0
Large format roll-feed printer	$10.00	1	0	0	0
Desktop systems	$3.00	13	0	0	0
Color printer	$3.00	0	0	0	0
HiROC Consumables					
DVD blanks (packs of 250)	$0.15	16	16	16	16
200GB LTO tapes (packs of 12)	$0.80	7	7	7	7
Misc printing materials	$2.00	2	2	2	2
Hardware Maintenance	$5.00	1	2	3	4
Yearly Totals		$524.9	$156.5	$161.5	$38.1

Appendix G – 1/10/93 MOS/GDS Peer Review

RFAs in 9 areas (summarized below) and our preliminary responses are:

I. The generation of calibrated (radiometric and geometric) HiRISE products will be a complicated process. The Review Board provided a number of actions for the calibration of HiRISE (Table 1, items 1-4). Note that the HiRISE team will have an independent calibration review. The calibration issues raised by the GDS peer review board could be folded into the results of the independent calibration review. Specific issues included ensuring that the required calibration data are collected pre-launch and reaching an agreement with the MRO Project to collect in-flight calibration data during cruise, transition orbit, and early mapping orbits to allow characterization of HiRISE in orbit.

HiRISE Calibration Review conducted 2/3/03; weekly Calibration Team teleconferences continue. Much Progress has been made. A calibration plan has been developed that identifies pre-launch, cruise, and in-orbit calibrations for the evaluation of the instruments radiometric and optical performance.

II. The HiRISE team's plan to support ATLO was not well defined at the review (item 5). In particular, coordination between LMA, Ball Aerospace, and the HiRISE team must be worked to support near-real-time analysis of ATLO data. It is critical that the HiRISE team plays a key role in the ATLO activities. In addition, it did not appear that adequate software would be available to support ATLO because the team's ATLO software requirements were not described during the review (item 6).

Ball has developed an ATLO Support Plan. HiTECH group has been working on HiCat database, for use during calibration and ATLO as well as cruise and Mars orbit. ATLO kickoff 7/03 meeting defined coordination between LMA, Ball, JPL, and HiROC. Plan summary described in EOP. HiROC system will be put in place to command instrument and access acquired data observations.

III. The development schedule and funding profile for the HiROC tools (HiPlan, HiDOg, etc.) were identified by the review board as being among the highest risks to the HiRISE project (items 7-14). The issue is that in the current plan significant resources will not be devoted to HiROC development until the start of Phase-E due to project funding profile constraints. These software tools are critical to the success of the investigation and must be ready by the start of operations. Also, the development of these tools will likely be very complex. Thus, every effort should be made to apply more resources to HiROC tool development earlier in the project lifecycle.

The HiROC development staffing for phase C/D has increased. The HiROC MOS/GDS Peer Review for the PDR identified no development staff in FY03, 1.5 FTE in FY04, and 3.75 FTE in FY05. Since the review, staffing has increased to 2.5 full time staff starting in July 2003. Staffing levels for 3.50 FTE in FY04, and 4.0 FTE in FY05. Project has adapted JMARS for MTT, which gives us a big head start on HiPlan. We plan to just develop HiRISE-specific plug-in modules to MTT. Meeting at ASU planned for early October. Development of HiCat and HiDOg are underway. UA HiTECH support was increased in May/03 new baseline contract, to support current group. We will have a contractual obligation to develop s/w needed for cal, ATLO, and cruise by early 2005, and HiTECH group is designing a system that will also be used in the PSP. However, we still have a big ramp-up in FY06 due to funding constraints, and there is risk. We are hoping for project reserves in FY05.

IV. Several issues were identified for the currently planned mission operations staffing levels (items 15-17). The issues centered on whether the HiRISE team had adequately estimated staffing requirements and the level of effort that EPO and the "people's camera" concept would require. The review board was concerned about the HiROC operations staffing issue because the HiRISE EOP already listed potential descopes for staffing.

We will eliminate staffing descope items. The People's Camera is a best level-of-effort. If we can't support it, then some activities won't happen.

V. The requirements and timeline for the uplink procedures needed better definition (items 18-20). There was also concern about how targeting requests would be accepted from the general science community and the public (items 21 and 22). The level of effort that would be required to support this activity could be high because each targeting proposer should be notified of the status of his request and notified again when data is available.

This again must be level-of-effort. If we can't keep up, then we won't keep up. Given NASA legalities we need 1 web-based system for all (scientist or not), but we can require sufficient work to eliminate poorly though-out requests. (unless someone writes a script--if someone is malicious enough they can defeat any system.) This cannot be something we depend on for success off the experiment. Co-Is and post-docs may need to submit most target requests.

VI. The review board recommended that additional thought and work was needed for the "Co-I of the Month" concept (items 23-25). In particular, the role, responsibilities, and training for this position need more definition. There also needs to be a better understanding of the level of commitment to be expected from the HiRISE Co-I's for this task.

We will make several changes. First, 1/4 FTE/yr of Co-I funding (not counting Eliason, Delamere, and Kirk) will be held in a separate pot and given to those who do make the commitment. There will be group training sessions. The first month must be in residence at HiROC then subsequent stints can hopefully be done from remote sites. Three full-time Targeting Specialists have been identified and can independently carryout observation planning independently.

VII. Procedures for instrument health monitoring and anomaly reporting were not clearly defined in the review (items 26 and 27). Of particular concern was the division of work between the HiRISE staff at UA and Ball Aerospace for instrument health monitoring and who would be the point of contact with the project for instrument health issues. Several other comments were submitted by the review board regarding HiRISE instrument operating procedures (items 28-32).

Added section to EOP

VIII. The review board noted that the hardware and staffing requirements for processing the large volume of HiRISE data will be great. Several concerns were noted as to whether the current HiRISE plans will be adequate for the data processing task (items 33-39). Additional analysis may be required to show the system will maintain the required throughput and will have enough margin to handle possible re-processing of data.

To address this we have changed the PDS delivery dates for high-level products that require HiJitter.

IX. The review board noted several areas where the HiRISE data release plans need further analysis (items 40-43). In particular, the use of HiROC as a PDS data node needs to be addressed and the timing of release for level 0 (EDR) and level 1c (calibrated products) needs additional consideration.

The HiRISE team has proposed to become a PDS HiRISE Data Node. A budget has been submitted to the PDS. EDR and RDR products will be released at the same time to avoid confusion by the science community.

Appendix H – Relevant Background Information on Marsoweb for HiWeb Development

Marsoweb capabilities (as of August, 2003)

Marsoweb (**http://marsoweb.nas.nasa.gov/**) is a collaborative web environment designed to allow the planetary community to better analyze, visualize and compare Mars Global Surveyor, Mars Odyssey and other data sets. The main purpose of the web site is to bring together data, tools, and information to facilitate landing site selection for the Mars Exploration Rover project. Over 120,000 distinct users from government, academia, and the general public have accessed the site to date.

The web site has grown out of a four-year effort by the Center for Mars Exploration (CMEX) at NASA Ames Research Center (ARC), the NASA Advanced Supercomputing (NAS) Division's Data Analysis Group at Ames, and the Mars Exploration Program. Web site development was overseen by project PI Virginia Gulick and implemented by Glenn Deardorff. Gulick interfaced with the MER project via her service as a member of the Mars Exploration Rover Landing Site Steering Group, directly with Steering Group Co-chairs Matt Golombek and John Grant, and with MER Project Scientist Joy Crisp. Marsoweb became a *de facto* official website of the landing site selection process and was referenced in the NASA AO that supported landing site selection studies.

Marsoweb has had two defining goals. The first has been to serve as a clearinghouse for all data and information relevant to the Mars Landing Site selection process. In this role we have archived studies of well over a hundred landing sites, provided easy access to unique relevant datasets, and generally done everything possible to facilitate the selection process to allow participation by the broadest possible range of contributors. The second goal was to remove barriers to data access by presenting standard datasets in browsable, user-friendly formats. In this second role, the website provides visualization tools to aid in data exploration and a quick and easy way to inter-compare disparate data sets and derived data products.

Current Marsoweb Features:

Although it is easier to become acquainted with the web site by use than by description, we list here the main features. Currently Marsoweb serves as a comprehensive archive of data pertinent to selection of landing sites for the 2003 Mars Explorer Rover ("MER 2003") missions. This interactive archive allows visual navigation of the candidate landing sites and various maps of data from the current Mars Global Surveyor (MGS) mission and from the Viking missions. Perusable data maps include MGS Mars Orbiter laser Altimeter (MOLA) elevations, thermal inertia derived from MGS Thermal Emission Spectrometer (TES) data, TES-derived mineralogy, MOLA pulse-width-derived vertical roughness, geology maps, and various data from the Viking Infrared Thermal Mapper (IRTM) instrument, in addition to Mars Digital Image Mosaic (MDIM) visible surface map composites combined with MOLA shaded relief maps. Interactive querying is enabled for TES thermal inertia and MOLA maps (to display data values) and geology maps (to display geologic units).

The MER 2003 facility serves to disseminate memoranda for the landing site selection community, and as a repository of landing site-related products produced by community members. It also includes 3D VRML scenes, whereby some of the data maps have been texture-mapped onto terrain grids from Viking Digital Terrain Models (DTM's), as well as a repository of high-resolution images of the potential landing sites from the MGS Mars Orbiter Camera (MOC); this repository served as a primary source of these images to the landing site community, and includes Java-based image processing and wide-angle MOC context images. New MOC images were added as they were made available by Malin Space Systems, and are easily navigated by clicking on their thumbnail outlines in regional image maps of the candidate landing sites.

In addition to landing site selection resources, Marsoweb also features interactive Java applet-based archives of global data that enable users to perform mouse-based interrogation of MGS data maps and geology maps, including the ability to query profiles created from user-drawn cross-sections in the data maps. Currently, the global data archive includes MOLA data, in both low-resolution (1/4-degree) cylindrical, and high-resolution (currently 1/32nd-degree; the 1/128th – degree MOLA data will be online very soon) Mercator versions, TES-derived thermal inertia data (1/8-degree resolution), geologic unit data (1/8-degree resolution), and composite MDIM/MOLA shaded relief images of the visible surface. In this second role, the website provides visualization tools to aid in data exploration and a quick and easy way to inter-compare disparate data sets and derived data products.

Other global data resources include graphical hyperlinks to the over 110,000 MOC images stored at Malin Space Systems, as well as the current catalog of THEMIS (Thermal Emission Imaging System) images from the Mars Odyssey. The MOC and THEMIS images are graphically depicted as outlines on the basemaps; their full-scale versions can be navigated to with one mouse click.

Other features include a servlet-based automated VRML atlas of Mars, whereby user-selected regions-of-interest (henceforth abbreviated as "ROI's") can be explored in 3D on the Web, using terrain data constructed from Viking Mars DTM's texture-mapped with surface imagery from the Viking MDIM's. The user can also choose to include high-resolution MOC images embedded in the terrain, as well as MOLA tracks rendered as color-coded elevation profiles "floating" slightly above the terrain.

There also exist archives of about a thousand MOC images from the MGS orbital insertion phase, whereby each MOC image has been manually rectified with surface features in MDIM images to provide co-registered Viking context images with superimposed MOC image thumbnails and outlines. (Different reference geoids used for Viking and MGS data result in slight coordinate offsets; this and other 2nd order disparities necessitate per-image visual registration for precise alignment of surface features in MOC and Viking MDIM images). A MOLA track archive (for data collected during the MGS orbital insertion phase) allows users to view the MOLA tracks in both plan view over MDIM surface images and in profile view; the profiles can be manually interrogated for elevation and coordinates. We are presently updating this interactive MOLA track archive with a more complete set of MOLA data.

Marsoweb features an archive of over 488 high-resolution (up to 3 meters/pixel) Mars Orbiter Camera (MOC) images of the candidate landing sites, to aid in the landing site selection process. This MOC archive allows the images to be graphically perused via regional image maps. The webpage for each MOC image contains several download options, image sub-frames (for more selective viewing), a MOC wide-angle context image showing the footprint of the (narrow-angle) MOC image, and a Java-based image processing tool suite which includes histogram display and equalization, manual contrast/brightness-stretching, zooming, cropping, and edge detection.

We have provided remote collaboration capabilities, such that geographically dispersed users can use Marsoweb to collaborate online. Instructions have been provided for users to enable cross-platform shared screen viewing using the Virtual Network Computing toolkit from AT&T Labs. This allows two or more collaborators to view each other's screen space, and to swap mouse control. Joining a collaborative session is as straightforward as typing in a URL. In addition, a shared electronic notebook has been deployed on Marsoweb, with sections for each of the prime MER 2003 landing sites. This Java-based "Electronic Notebook" is from the Environmental Molecular Sciences Lab's Toolkit for Collaboratory Development. Users can upload and share movies, images, and other files, and create content with the built-in word processor, image-capturing tool, Latex-based equation editor, form editor, and whiteboard (for creating diagrams and adding annotations to images).

Appendix I – Supplemental Material for HiWeb

HiWeb and the People's Camera Concept

In order for the "People's Camera Concept" to be realized, the HiRISE team needs a straightforward easy to use web interface for all to acquire, view, and analyze, HiRISE observations in context with other Mars data. This interface known as HiWeb will provide support for submission of the HiRISE team's, MRO project's, science community's and the general public's observation suggestions (~2,000 pointed observations). NASA Quest will help educate students and the general public about Mars and filter their observation suggestions via web event opportunities involving HiRISE team members in FY06 and FY08. In addition, HiWeb's automated filtering image target suggestion process will also support public image suggestions throughout the duration of the mission. HiWeb will also serve as the data distribution portal for acquiring and downloading HiRISE images.

HiWeb's roles:

- Uplink role``
- Downlink role
- Public website (see http://marsoweb.nas.nasa.gov/HiRISE)
- HiRISE image distribution site (to serve as a potential PDS Sub-Node for HiRISE images)

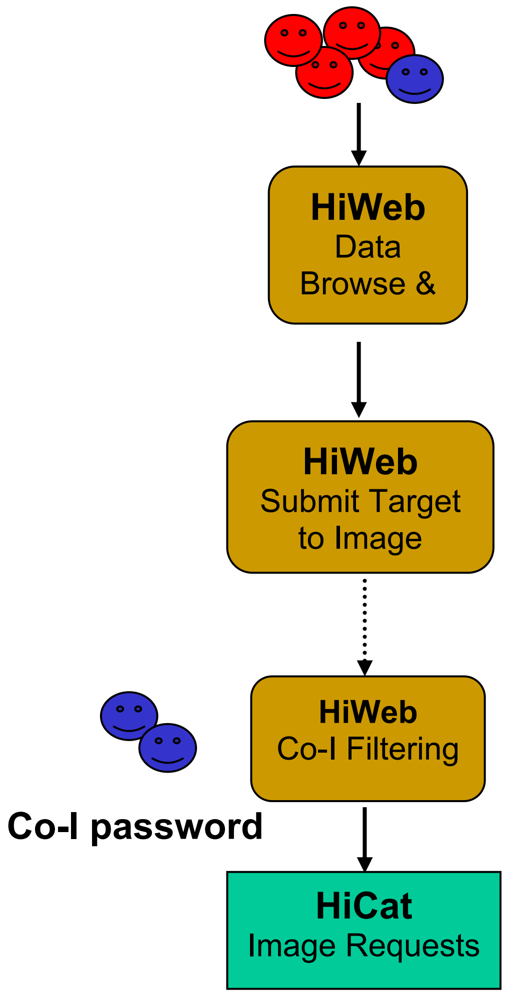

Figure 1: HiWeb's uplink role provides an observation suggestion system. HiWeb will provide a user-friendly platform-independent interface with browse, view & analysis capabilities. Users will be able to 1**)** compare, overlay, & analyze HiRISE images with multiple, disparate Mars data sets (e.g., MDIM's, shaded relief, geology, surface roughness, MOLA, TES & Viking TI, TES & THEMIS mineralogy, GRS data, MOC, THEMIS image & temps, etc.); 2) view past, present & projected future HiRISE orbital ground tracks & image swaths; 3) select and delineate target region of interest by using constrained "rubber band" & direct coordinate entry; 4) input imaging constraint specifications (needed resolution, S/N, lighting geometry, etc.); 5) provide tools for Co-I's to view, evaluate, and filter suggestions and forward to HiCat; 6) provide automatic email notification of receipt of suggestion to user; and 7) provide several security levels as needed for Team, MRO Project, Science community, and E/PO.

HiWeb Science Community & E/PO User Experience

- Log in to system-- register as science community, school or general public
- Public version is presented with instructions and educational modules to help guide them through selection.
- Browse MDIM's (zoom & pan) or enter coordinates of area of interest
  - All previous mission image data will be seamlessly incorporated.
- Browse data overlays, see list of all previous imaging (link to PDS), overlay & process (if needed) HiRISE images with Mars images or data from other Mars missions or other MRO instruments.
- Interactively query data if required (e.g., topographic. profiles from user-drawn cross-sections).
- Activate targeting module for interactive target selection
  - Pop-up box queries target category & desired & acceptable resolution, S/N, season, etc.
  - Overlaid, constrained rubber-band target selection
  - Text entry for short science justification with optional links to relevant additional information (papers, archived presentations, etc.) & short name
  - “Submit” will activate a servlet to add proposed target to HiRISE proposed target catalog.
- Enter more targets or log out

HiRISE Team Member User Experience

- HiRISE team member logs in, presented list of newly submitted target suggestions in their assigned category (e.g., periglacial, fluvial, aeolian features) from science community and filtered student/public requests.
- Clicking on target name gives similar view/interface as user
  - Browse region, overlaid data, etc.
  - Adjust constraints if desired
  - Prioritize target suggestions
    - High priority suggestions sent to HiROC
    - E-mail message to user generated automatically
    - Automatic record keeping

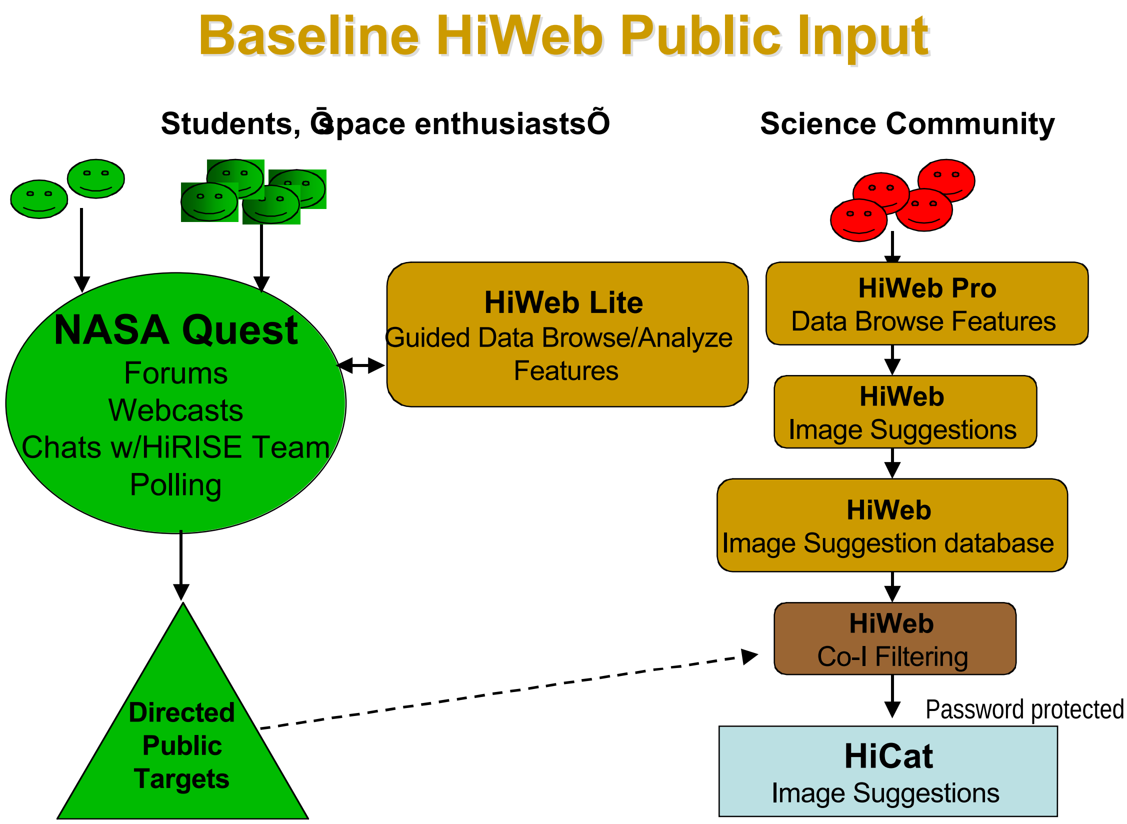

Figure 2: Potential baseline (secure) plan. All E/PO (student and public) image suggestions would be filtered through E/PO partner. These "high-priority" E/PO image suggestions would be generated as a result of E/PO partner's web events and sent directly to the appropriate Co-I. Users identified as science community would access HiWeb Pro. Image suggestions would be sent to a HiWeb data base. Co-Is would then access this database, prioritize suggestions and submit high priority suggestions into the HiCat database.

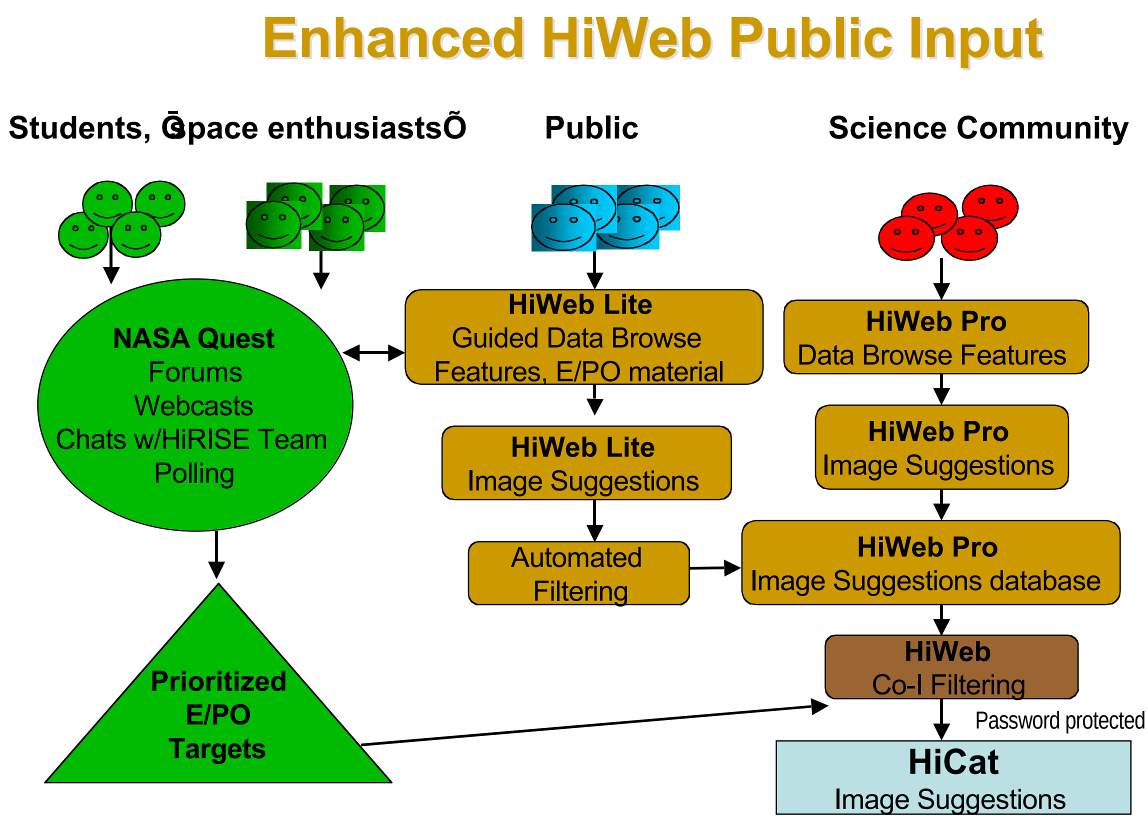

Figure 3: The desired HiWeb Public input plan.