SOHO

J.B. Gurman
US Project Scientist for *SOHO*

Bernhard Fleck
ESA Project Scientist for SOHO

Presentation to the Heliophysics Senior Review
2010 April 21

Outline

- Why a Bogart mission?
- Updates to proposal
- Backup slides on budget and programmatic concerns, if of interest

Why a Bogart mission? (I)

- Solar Dynamics Observatory (SDO) Science and Technology Definition Team (STDT) Report determined that SDO needed, among other measurements: "White-light polarization brightness images of the solar corona to record and monitor coronal evolution and restructuring important for generating *geoeffective* interplanetary disturbances." [emphasis mine]
- Presumably, this is an important objective for Heliophysics as a whole.

Why a Bogart mission? (II)

- SDO STDT report called for the following instrument complement:
  - Helioseismic/Magnetic Imager
  - Atmospheric Imaging Array
  - EUV Spectral Irradiance Monitor
  - Coronagraph
  - &c.

Why a Bogart mission? (III)

- Following the Phase A deselection of SHARPP (EUV imagers plus coronagraphs), and an unsuccessful attempt to have Europe provide a coronagraph, we were left with:
  - Helioseismic/Magnetic Imager: HMI
  - Atmospheric Imaging Array: AIA (alternate proposal)
  - EUV Spectral Irradiance Monitor: EVE
  - Coronagraph: *SOHO* LASCO

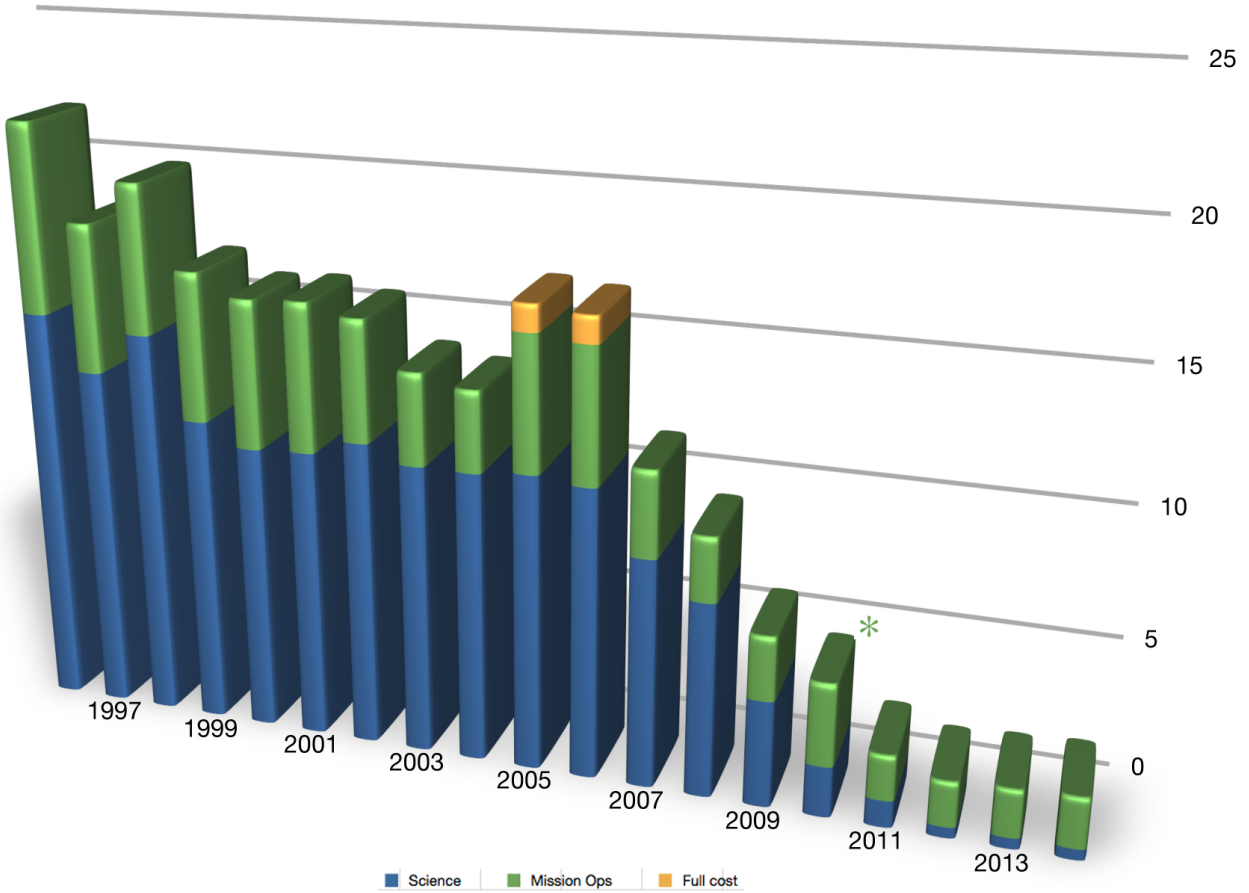
Operating a Great Observatory on a SMEX Budget

NASA *SOHO* MO&DA ($M), FY1996 - FY2014 (est.)

Figures are *not* adjusted for inflation.

* FY10 budget includes contingency that may be rephased if not used.

After FY10, science mean science operations *only*, not research.

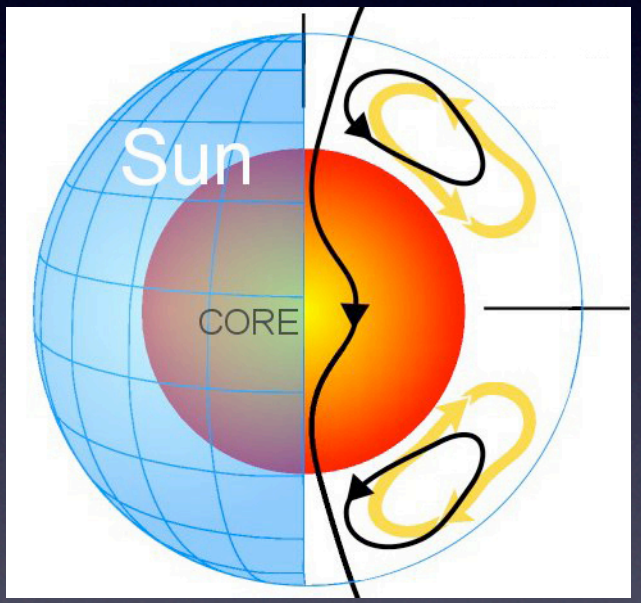


Updates to proposal

- Science
  - A solar cycle's worth of meridional circulation
  - Sungrazing comet caught in the act of evaporating
  - Publication update
- Archive status
- Communications (formerly known as public affairs)

Science Updates (I) Meridional Circulation

- Amplitude (10 - 20 m s^{-1}) more than an order of magnitude smaller than granulation (~3 km s^{-1}), supergranulation (~300 m s^{-1}), or differential rotation (~170 m s^{-1}), so speeds and even directions reported in the past differ significantly
- Flow estimates used in flux transport models of cyclical activity

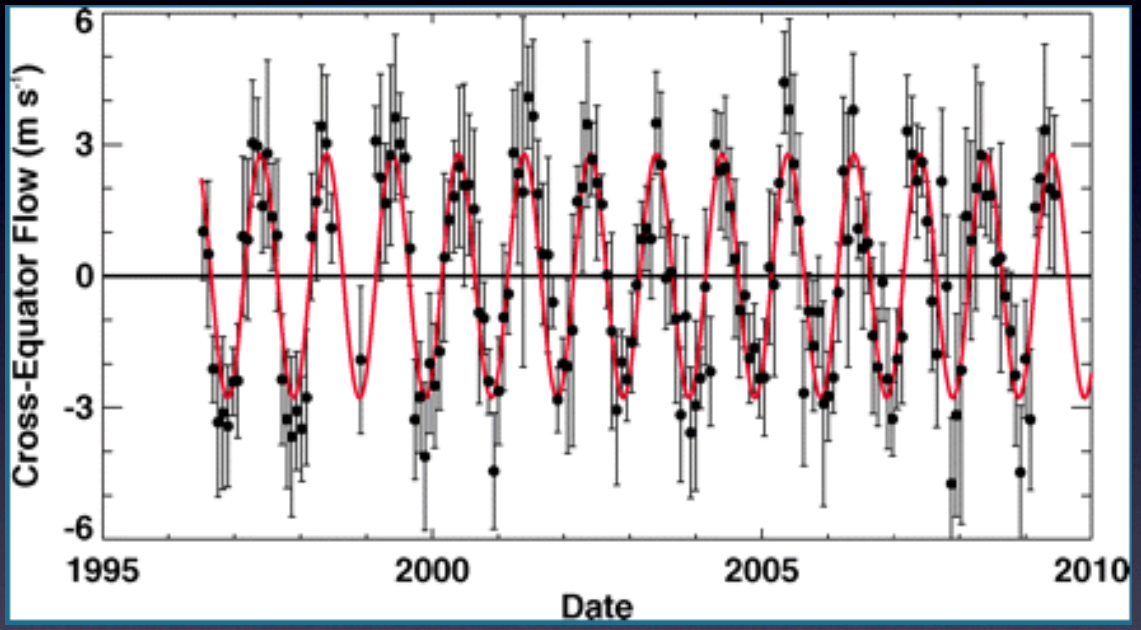


Meridional Circulation (II)

Hathaway and Rightmire (2010, Science, 327, 1350. DOI: 10.1126/science.1181990) used MDI magnetograms to measure meridional flow over the period 1996 - 2009

Cross-correlated small magnetic features (*not* sunspots) in an 11 x 600 pixel mask centered at disk center in successive, 1024 x 1024-pixel MDI magnetograms (8 hour cadence)

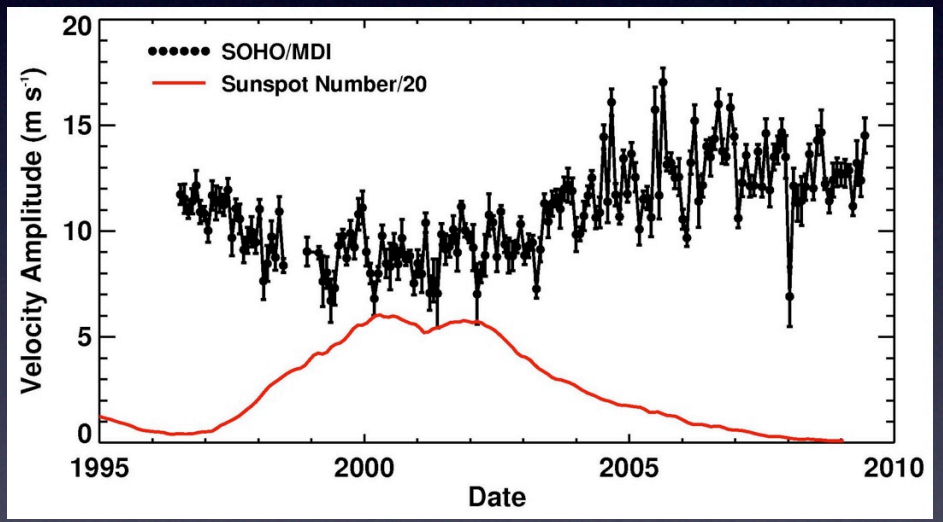
Measurements require a 0.08° correction to the solar B angle value normally assumed



- Excellent example of the kind of science that can be done with an entire cycle's worth of measurements (> 60,000 magnetograms)

Meridional Circulation (III)

"The source of the ***disagreement between the surface flux transport models (6–10) and the flux transport dynamo models (11, 12)*** can be seen in the latitudinal distribution of magnetic polarities in these models. The dynamo models have fields of one polarity centered on the sunspot latitudes, whereas the surface models have bands of opposite magnetic polarity on either side of the sunspot latitudes, as is observed. A fast meridional flow in the dynamo models carries elements of only one polarity to the poles. This rapidly erodes the old polar fields and produces strong polar fields of the opposite polarity. ***A fast meridional flow in the surface models inhibits opposite polarities from canceling each other across the equator and carries elements of both polarities to the poles (with a slight excess of elements with the polarity of the poleward side of the sunspot latitudes). This requires a longer time to reverse the old polar fields and builds up weaker polar fields of the opposite polarity. The variations we observe in the strength of the poleward meridional flow help the surface flux transport models explain (22, 23) the production of weaker polar fields (13) and this long quiet minimum based on the faster meridional flow found after 2004.***"

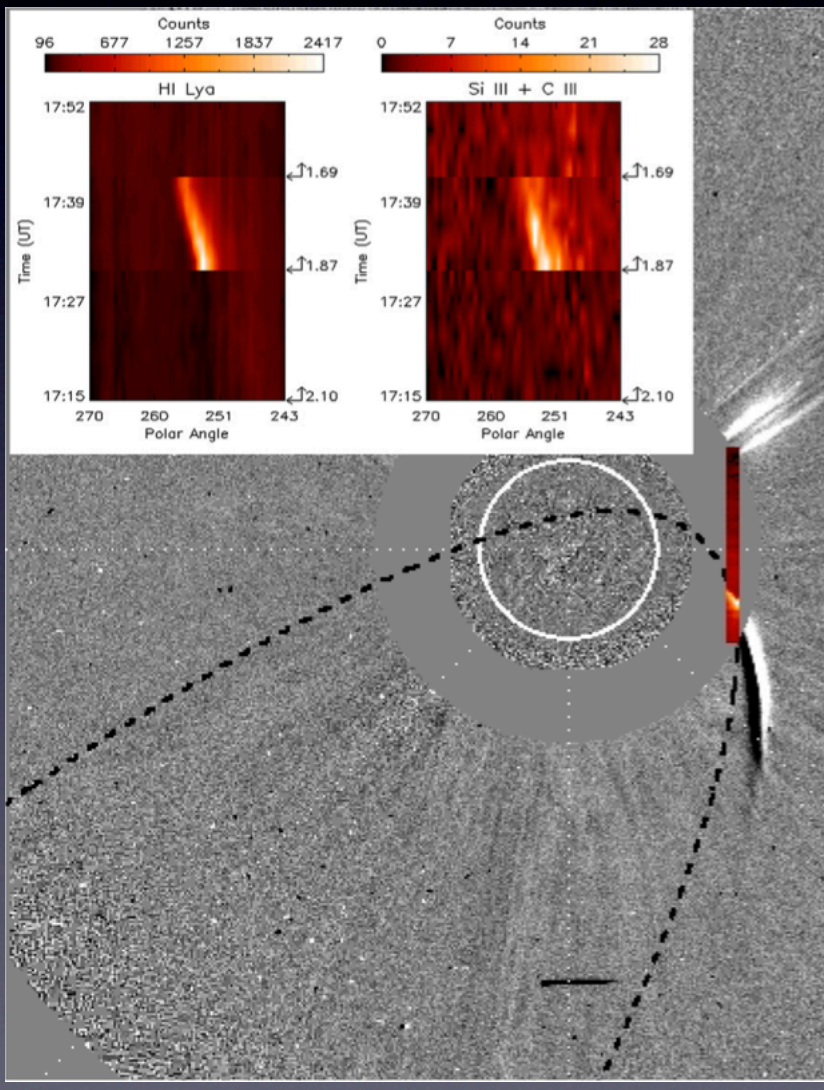


Science Updates (II) Serendipity: Comets

- Ciaravella, Raymond, and Giordano (2010, ApJ, L69. DOI: 10.1088/2041-8205/713/1/L69) report on evidence for dust sublimation in UVCS spectra of Si III and C III lines from sungrazing comet C-2003K7
  - Serendipitous observation as part of a synoptic scan of the corona
  - Outgassing rate: more than an order of magnitude greater than that from other UVCS-observed sungrazers
  - Light curves peak at 10 - 12, again at 6 solar radii, indicative of erosion/breakup events

Comet Outgassing

- Derived outgassing rates of 0.7 - 3.9 x 10^6 g s^{-1} (Si) and 1.7 - 15 x 10^4 g s^{-1} (C)
- If the Si atoms originate in the evaporation of molecules of forsterite or olivine, mass loss rate from dust is ~ 4 - 50 x 10^6 g s^{-1}
- All grains < 12 cm in diameter likely to evaporate in < 10 min at observed distance of 3.37 solar radii



Uptake of SOHO data

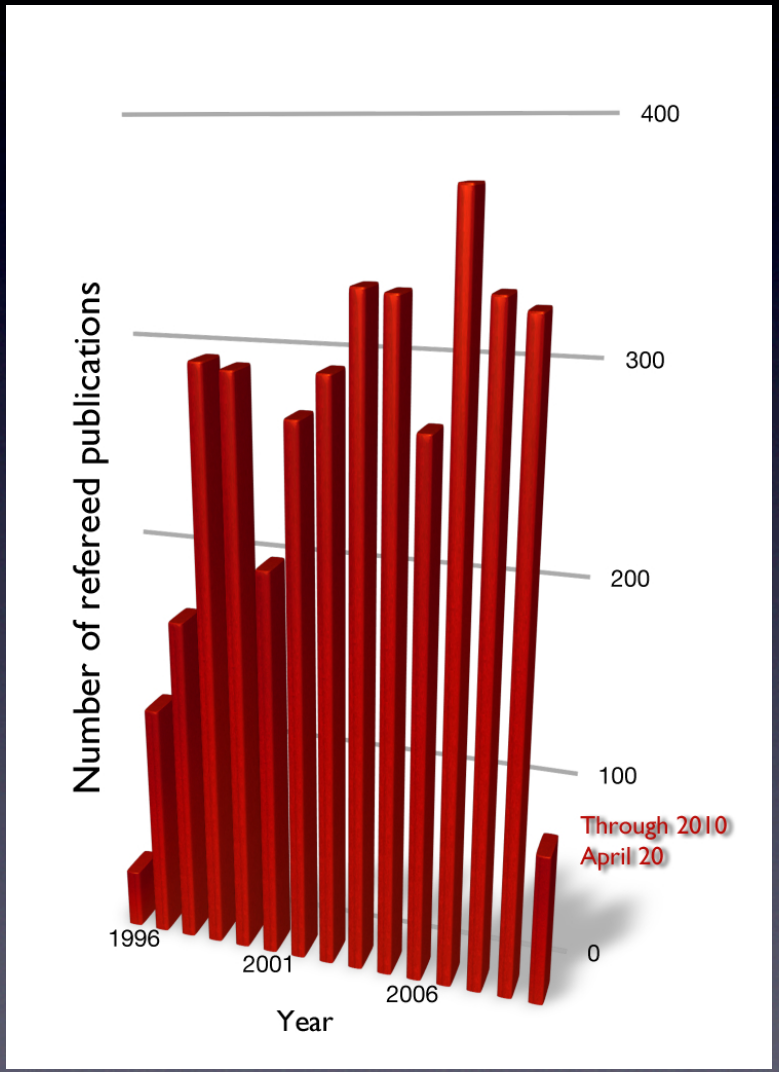
- *SOHO* Website: > 99 Tbyte of downloads in 2009/02 - 2010/01 (+ 21 Tbyte from European mirror)
- > 0.35 Tbyte of *SOHO* EIT data served by SDAC in 2008/01 - 2010/02
- 2.4 Tbyte of EIT data distributed on user-owned hard drives in 2009
- Most of the > 25 Tbyte of data distributed through VSO searches in 2009 were *SOHO* data
- > 1685 comets discovered, over half by amateurs, using freely downloadable *SOHO* LASCO coronagraph images (FITS files), since 1996 (well over half of all the comets for which orbital elements are known)

Calendar Year	Refereed Journals only
1996	31
1997	124
1998	172
1999	297
2000	294
2001	203
2002	274
2003	295
2004	332
2005	330
2006	272
2007	374
2008	331
2009	325
2010 (to April 20)	80
Total	3734

SOHO papers in the refereed literature

Uptake of SOHO data

- *SOHO* Website: > 99 Tbyte of downloads in 2009/02 - 2010/01 (+ 21 Tbyte from European mirror)
- > 0.35 Tbyte of *SOHO* EIT data served by SDAC in 2008/01 - 2010/02
- 2.4 Tbyte of EIT data distributed on user-owned hard drives in 2009
- Most of the > 25 Tbyte of data distributed through VSO searches in 2009 were *SOHO* data
- > 1685 comets discovered, over half by amateurs, using freely downloadable *SOHO* LASCO coronagraph images (FITS files), since 1996 (well over half of all the comets for which orbital elements are known)



SOHO papers in the refereed literature

Archive Status (I)

http://soho.nascom.nasa.gov/data/archive/index_gsfc.html

Available Data as of April 17, 2010

INSTRUMENT	LATEST DATA	UPDATED ON
CDS	2010-04-16	2010-04-17
CELIAS	2010-04-05	2010-04-08
COSTEP	2010-01-29	2010-02-23
EIT	2010-03-09	2010-04-03
ERNE	2010-03-04	2010-03-11
GOLF	2010-02-27	2010-03-09
LASCO	2009-12-30	2010-03-20
MDI	2010-02-28	2010-04-17
SUMER	2009-11-10	2010-02-11
SWAN	2010-01-26	2010-02-23
UVCS	2010-01-21	2010-03-04
VIRGO	2010-04-15	2010-04-17

Archive Status (II)

- CELIAS MTOF updates
  - Proton monitor (PM) solar wind data (ASCII)
  - MTOF solar wind heavy ion abundances (CDF)
- LASCO updates
  - Level 1 (calibrated) C2, C3
    - Current through 2009•12
    - Updating through 2010•03

Communications (I)

- ....not the earth-to-spacecraft sort, but the (formerly known as) Public Affairs sort
- *SOHO* "Hot shots:" Covered the meridional circulation story last month
  - First reported by Science @NASA
- Our long-time SOHO media specialist, Steele Hill, went to work nearly full-time for STEREO in 2007
  - Now nearly full-time on SDO (0.7 FTE)
- *Story now is heliophysics, not a single mission*

Communications (II)

- *SOHO* Website has carried "Pick of the Week" features since 2001, in an agreement with the American Museum of Natural History/Rose Center; now carried by many museums
  - Pick of the Week is as likely to be STEREO-related as SOHO.
  - Will naturally transition to SDO stories

Supporting Material

- *Relation to Roadmap research focus areas (RFAs)*
- *Budget concerns for FY11 - 14*
- *Letters of support/interagency future of Sun-earth line synoptic measurements*
- *DSN statistics*

Roadmap: "Frontier"

Research Focus Areas

F1 Magnetic reconnection

F2 Particle acceleration and transport

F3 Ion-neutral interactions

F4 Creation and variability of magnetic dynamos

Open the Frontier to Space Environmental Prediction

The Sun, our solar system, and the universe consist primarily of plasma. Plasmas are more complex than solids, liquids, and gases because the motions of electrons and ions produce both electric and magnetic fields. The electric fields accelerate particles, sometimes to very high energies, and the magnetic fields guide their motions. This results in a rich set of interacting physical processes, including intricate exchanges with the neutral gas in planetary atmospheres.

Although physicists know the laws governing the interaction of electrically charged particles, the collective behavior of the plasma state leads to complex and often surprising physical phenomena. As the foundation for our long-term research program, we will develop a comprehensive scientific understanding of the fundamental physical processes that control our space environment.

The processes of interest occur in many locations, though with vastly different magnitudes of energy, size, and time. By quantitatively examining similar phenomena occurring in different regimes with a variety of techniques, we can identify the important controlling mechanisms and rigorously test our developing knowledge. Both remote sensing and in situ observations will be utilized to provide the complementary three-dimensional, large-scale perspective and the detailed small-scale microphysics view necessary to see the complete picture.

Note: Refers to *SOHO* Bogart mission, not the "classic" *SOHO* mission

Roadmap: "Home"

Research Focus Areas

H1 Causes and evolution of solar activity

H2 Earth's magnetosphere, ionosphere, and upper atmosphere

H3 Role of the Sun in driving change in the Earth's atmosphere

H4 Apply our knowledge to understand other regions

Understand the Nature of Our Home in Space

Humankind does not live in isolation; we are intimately coupled with the space environment through our technological needs, the solar system bodies we plan to explore, and ultimately the fate of our Earth itself. We regularly experience how variability in the near-Earth space environment affects the activities that underpin our society. We are living with a star.

We plan to better understand our place in the solar system by investigating the interaction of the space environment with the Earth and the effect of this interaction on humankind. We plan to characterize and develop a knowledge of the impact of the space environment on our planet, technology, and society. Our goal is to understand the web of linked physical processes connecting Earth with the space environment.

Even a casual scan of the solar system is sufficient to discover that habitability, particularly for humankind, requires a rare confluence of many factors. At least some of these factors, especially the role of magnetic fields in shielding planetary atmospheres, are subjects of immense interest to heliophysics. Lessons learned in the study of planetary environments can be applied to our home on Earth, and vise versa, the study of our own atmosphere supports the exploration of other planets.

Roadmap: "Journey"

Research Focus Areas

J1 Variability, extremes, and boundary conditions

J2 Capability to predict the origin, onset, and level of solar activity

J3 Capability to predict the propagation and evolution of solar disturbances

J4 Effects on and within planetary environments

Safeguard the Journey of Exploration

NASA's robotic spacecraft continue to explore the Earth's neighborhood and other targets in the heliosphere. Humans are expected once again to venture onto the surface of the Moon and one day onto the surface of Mars. This exploration brings challenges and hazards. We plan to help safeguard these space journeys by developing predictive and forecasting strategies for space environmental hazards.

This work will aid in the optimization of habitats, spacecraft, and instrumentation, and for planning mission operation scenarios, ultimately increasing mission productivity. We will analyze the complex influence of the Sun and the space environment, from origin to the destination, on critical conditions at and in the vicinity of human and robotic spacecraft. Collaborations between heliophysics scientists and those preparing for human and robotic exploration will be fostered through interdisciplinary research programs and the common use of NASA research assets in space.

Proposed Mission, FY11 - FY14

- Not really *SOHO* as we knew it: the "Bogart" mission
  - Will be operating a Great Observatory as a SMEX
  - Have already automated all operations except orbit trim, momentum management, and rolls
  - *The reason NASA wants to continue SOHO operations is to continue the LASCO earth-Sun line coronagraphy not available on SDO*
- MDI will cease operations by end of CY10, after intercalibration with SDO/HMI
- SUMER operations severely limited by hardware issues
- UVCS, CELIAS MTOF operations will not last the four years under the current guidelines

Current Year Budget and FY11-14 Guidelines ($M)

	FY10	FY11	FY12	FY13	FY14
Mission Ops	2.03	1.61	1.66	1.68	1.69
Science Ops	1.99	1.04	0.98	1.01	1.04
Total	4.02	2.65	2.64	2.69	2.73
Guideline	5.00	2.68	2.10	2.20	2.29
Needed			0.54	0.49	0.44

"Known unknowns" in FY10 include: FOT overtime for MDI-HMI intercalibration; moving people and offices to Bldg. 21 from Bldgs. 3 and 26; moving hardware; new network infrastructure

If no additional funds are available in out years, will have to turn off two US-led instruments (UVCS and CELIAS MTOF).

Budget Detail

Much lower outyear budgets than given in guidelines after 2008 review

Will have to turn off two US-led instruments if we cannot rephase unspent funds

Rephasing has worked so far

		Project Name:	**SOHO**					
		I. FY10 – FY014 NASA Guideline with full-cost breakout ($K)						
			FY10	FY11	FY12	FY13	FY14	Total
		Total	5,000.0	2,682.0	2,101.0	2,200.0	2,289.0	**14,272.0**
		II. FY10 – FY14 '5-way' Functional Breakdown ($K)						
			FY10	FY11	FY12	FY13	FY14	
		1. Development	0.0	0.0	0.0	0.0	0.0	
		2.a Space Communications Services	12.1	12.5	12.8	13.2	13.6	
	[1]	2.b Mission Services	1,716.7	1,416.2	1,459.2	1,458.8	1,458.5	
		2.c Other Mission Operations	302.6	186.2	195.0	205.7	216.2	
		3. Science Operations Functions	1,938.8	1,040.7	979.9	1,011.7	1,044.5	
		4a. Science Data Analysis	50.0	0.0	0.0	0.0	0.0	
		4b. Guest Observer Funding	0.0	0.0	0.0	0.0	0.0	
		5. E/PO	0.0	0.0	0.0	0.0	0.0	
		Total*	4,020.2	2,655.6	2,646.9	2,689.4	2,732.8	
		*Totals for Table II should be identical to totals in Table I.						
		III. FY10 – FY14 Instrument team breakdown ($K)						
			FY10	FY11	FY12	FY13	FY14	
		Stanford (MDI)	660.0					
	[2]	SAO (UVCS)	464.0	372.0	385.0	398.5	412.4	
		NRL (LASCO)	125.0	50.0	50.0	50.0	50.0	
	[3]	UMD (CELIAS MTOF)	267.0	159.0	155.3	160.7	166.3	
		USC (CELIAS SEM)	107.0					
		LASCO (GSFC)	343.2	355.2	367.6	380.5	393.8	
		Other science teams						
		Other mission expenses	2,054.0	1,719.4	1,683.4	1,699.7	1,710.3	
		Total	4,020.2	2,655.6	2,641.3	2,689.4	2,732.8	**14,739.4**
		Total assuming instr. terminations**	4,020.2	2,655.6	2,101.0	2,130.2	2,154.1	13,061.2
		**Totals for Table III should be identical to totals in Table I.						
		IV. FY10 – FY14 '5-way' Breakdown for in-Kind contributions ($K)						
			FY10	FY11	FY12	FY13	FY14	
		1. Development						
		2.a Space Communications Services	9,279.6	9,549.4	9835.9	10,131.0	10,434.9	
		2.b Mission Services	54.5	56.2	57.9	59.6	61.4	
		2.c Other Mission Operations	75.6	79.0	85.6	88.2	90.8	
		3. Science Operations Functions	*	*	*	*	*	
		4a. Science Data Analysis	*	*	*	*	*	
		4b. Guest Observer Funding						
		5. E/PO						
		Total	9,409.7	9,684.6	9,979.4	10,278.8	10,587.1	
	*	European national funding of European PI teams						
	[1]	Mission services line in FY10 includes FOT overtime contingency for support of continuous campaign to intercalibrate MDI and HMI						
	[2]	To fit within annual guidelines, UVCS operations must cease by the end of FY11; can continue until at least the end of FY13 if rephasing allowed						
	[3]	To fit within annual guidelines, CELIAS MTOF operations must cease by the end of FY11; should be able to extend into FY14 if rephasing allowed						

Sun-Earth Line Synoptic Measurements

Without asking the original requestor about their intent, I think I can answer your question as to our desired utilization of your imagery. The vast majority of what we do relates to current and future events. As a result, our guys could best use a feed of current imagery.

TSgt Pickering (CC'ed on this message) is in charge of the team which coordinates the technical issues for external communications. He, or one of his guys, will help establish and verify everything is operational and valid for the communications between our systems.

The AFWA SEMS Task Group (also CC'ed on this message) will need to open an SCR to make the appropriate changes on JAAWIN to host the files once we receive them. I expect SEMS will be able to keep the discussions in house with TSgt Pickering's team for things like filenames. After all, TSgt Pickering's team is going to have to gain that knowledge to properly handle the files once receipt begins.

I hope that answers questions enough for everyone to be ready to move forward. If not, well, all of you know at least one method of contacting me so we can resolve any outstanding concerns!

// SIGNED //
JEFFREY J HUSTON, MSgt, USAF
NCOIC, Operations Requirements
2SYOS/DOR
DSN 271-0690
Commercial (402)294-0690

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
National Centers for Environmental Prediction
Space Weather Prediction Center
325 Broadway W/NP9
Boulder, CO 80305
Telephone: (303) 497-3311 Fax: (303) 497-4006
Mobile: (720) 384-7659 Tom.Bogdan@noaa.gov

Dr. Thomas J. Bogdan
Director

MAR 2 4 2010

Dr. Joseph Gurman
Facility Scientist, Solar Data Analysis Center
NASA Goddard Space Flight Center
Solar Physics Branch/Code 671.1
Greenbelt, MD 20771

Dear Joe,

As director of NOAA's Space Weather Prediction Center, I am writing you to express our support for the continued operation of the SOHO/LASCO coronagraphs. It is our understanding that once SDO is commissioned, SOHO/LASCO will be operated in the so-called "Bogart" mode, with downlinks occurring three times per day, with the effective cadence being increased to something like 10 min.

SWPC has taken the leap to transition the first operational numerical space weather prediction models at NWS/NCEP. This model will become operational in late 2011. Coronagraph observations provide the optimal input parameters for WSA/ENLIL. For this reason, NOAA has included funding for the procurement of an operational coronagraph expected to launch in late 2013. To ensure there are no gaps in service, the SOHO coronagraph data will be used to drive the WSA/ENLIL model. It is of vital concern to us that coronagraph observations be continued backup (e.g., solar on-disk Xray and EUV images, the temporarily available STEREO data, etc.), the underlying premise in this undertaking is that a reliable stream of coronagraph images be ensured. SWPC would therefore like to make it clear to all that continued operation of the LASCO instrument serves directly the National interest.

Let me emphasize that from the SWPC standpoint, the constraints on cadence and downlink are dictated by the field of view of the instrument in conjunction with the precept that an absolute minimum of three images are needed to determine the speed, size, and direction of a worst-case CME (one traveling in excess of 3000 km/sec). Taking into account realistic latencies in acquiring and processing the relevant images and the time it takes to compute and interpret a forecast, a 10-min cadence for C3 images and three-times-per-day downlink is required to satisfy SWPC's forecast needs.

Sincerely,

Thomas J. Bogdan

Cc: Vic Pizzo, SWPC

SOHO DSN Statistics