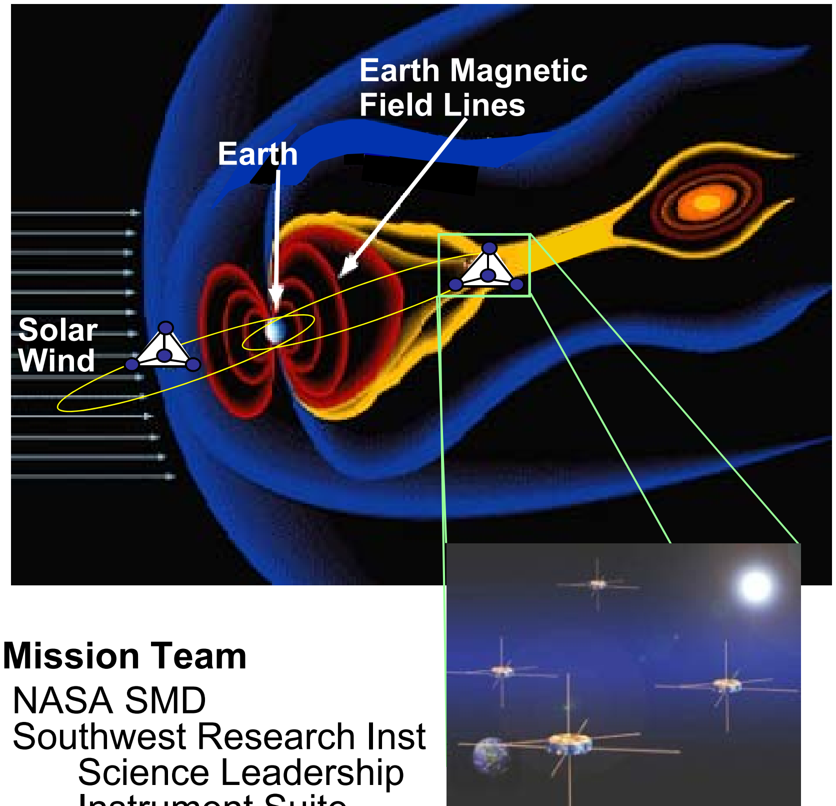
Magnetospheric Multiscale Mission (MMS) Overview

Craig Tooley
MMS Project Manager

MMS Mission Overview

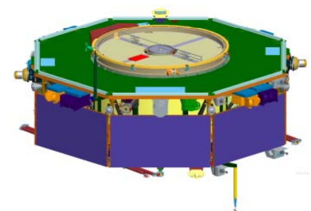


Science Objectives

Discover the fundamental plasma physics process of reconnection in the Earth's magnetosphere

- Temporal scales of milliseconds to seconds
- Spatial scales of 10s to 100s of km

Mission Description



4 identical satellites

Formation flying in a tetrahedron with separations as close as 10 km

2 year operational mission

Orbit

Elliptical Earth orbits in 2 phases

- Phase 1 day side of magnetic field 1.2 R_E by 12 R_E
- Phase 2 night side of magnetic field 1.2 R_E by 25 R_E

Significant orbit adjust and formation maintenance

Instruments

Identical *in situ* instruments on each satellite measure

- Electric and magnetic fields
- Fast plasma with composition
- Energetic particles
- Hot plasma composition

Spacecraft

Spin stabilized at 3 RPM

Magnetic and electrostatic cleanliness

Launch Vehicle

4 satellites launched together in one Atlas V

Mission Status

Currently in Phase C, Launch in 2014

Mission Team

NASA SMD

Southwest Research Inst

- Science Leadership
- Instrument Suite
- Science Operations Center
- Science Data Analysis

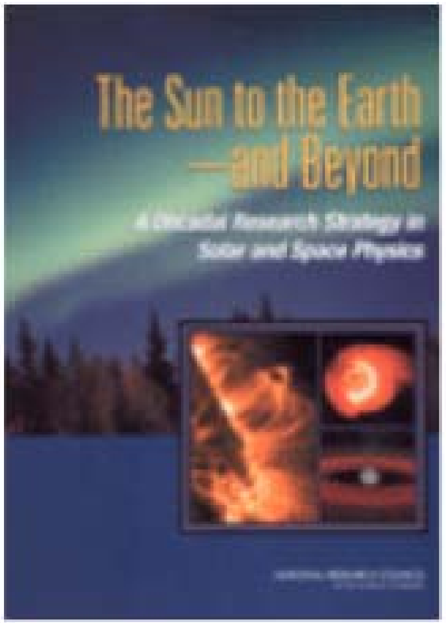
NASA GSFC

- Project Management
- Mission System Engineering
- Spacecraft
- Mission Operations Center

NASA KSC

- Launch services

Why MMS? - Solar and Space Physics Decadal Survey Highest Priority



National Academy of Sciences Decadal Survey in Solar and Space Physics, 2002

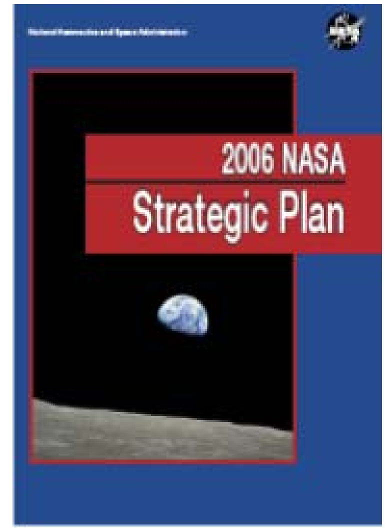
Moderate	1	Magnetospheric Multiscale	Four-spacecraft cluster to investigate magnetic reconnection, particle acceleration, and turbulence in magnetospheric boundary regions.
	2	Geospace Network	Two radiation-belt-mapping spacecraft and two ionospheric mapping spacecraft to determine the global response of geospace to solar storms.
	3	Jupiter Polar Mission	Polar-orbiting spacecraft to image the aurora, determine the electrodynamic properties of the Io flux tube, and identify magnetosphere-ionosphere coupling processes.
	4	Multispacecraft Heliospheric Mission	Four or more spacecraft with large separations in the ecliptic plane to determine the spatial structure and temporal evolution of coronal mass ejections (CMEs) and other solar-wind disturbances in the inner heliosphere.
	5	Geospace Electrodynamic Connections	Three to four spacecraft with propulsion for low-altitude excursions to investigate the coupling among the magnetosphere, the ionosphere, and the upper atmosphere.
	6	Suborbital Program	Sounding rockets, balloons, and aircraft to perform targeted studies of solar and space physics phenomena with advanced instrumentation.
	7	Magnetospheric Constellation	Fifty to a hundred nanosatellites to create dynamic images of magnetic fields and charged particles in the near magnetic tail of Earth.

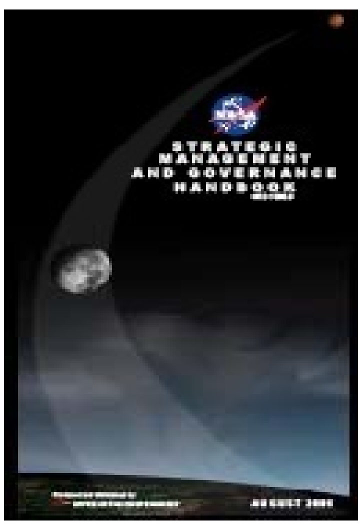
NASA Implementation of MMS Mission

NASA 2006 Strategic Plan

"Sub-goal 3B: Understand the Sun and its effects on Earth and the solar system."

"By 2013, NASA plans to launch the Magnetospheric Multiscale Mission to observe the fundamental processes responsible for the transfer of energy from the solar wind to Earth's magnetosphere and for the explosive release of energy during solar flares."





NPD 1000.0 Strategic Management And Governance Handbook

Provides rationale for GSFC spacecraft development

Essential competency of Agency must be maintained within the civil service workforce

MMS Programmatic History

12/99	MMS Science and Technology Definition Team (STDT) report published
5/02	Formulation Authorization Document signed
1/03	MMS Announcement of Opportunity released
10/03	Phase A Instrument Teams selected
4/05	Instrument Concept Studies completed
5/05	Southwest Research Institute selected as Instrument Suite contractor
5/06	Development of spacecraft assigned to GSFC
9/06	Mission Definition Review-06, Preliminary Non Advocate Review-06
9/07	Systems Requirements Review/Mission Definition Review/Preliminary NAR
11/07	MMS approved for Phase B at Key Decision Point-B
6/08	System Definition Review (project chaired)
5/09	Mission PDR/Non Advocate Review
6/09	MMS approved for implementation at Key Decision Point-C
8/10	Mission CDR
12/10	NASA SMD APMC approval to move forward to KDP-D
7/11	APMC approval of MMS request for UFE $ after MMS SRB Progress Review
1/12	*Instrument Suite and Mission System Integration Reviews*

MMS Team

- **NASA Science Mission Directorate Heliophysics Division**
- **Solar Terrestrial Probes Program**
- **MMS Project**
  - **Southwest Research Institute (SwRI) Solving Magnetospheric Acceleration, Reconnection, and Turbulence (SMART)**
    - James Burch from SwRI is the MMS Principal Investigator
    - Roy Torbert from UNH is the MMS Deputy PI
    - Instrument Co-Is
      - Fields: Roy Torbert, UNH
      - Fast Plasma Investigation: Craig Pollock, GSFC
      - Energetic Particles Detector: Barry Mauk, APL
      - Hot Plasma Composition Analyzer: Dave Young, SwRI
      - Active Spacecraft Potential Control: Klaus Torkar, IWF, Austria
    - Science Operations Center from UC LASP (Dan Baker)
    - Education and Public Outreach from Rice University (Pat Reiff)
    - Theory and Modeling from GSFC (Michael Hesse)
  - **GSFC**
    - Project management
    - Project science
    - Mission systems engineering
    - Spacecraft development
    - System Integration and Test
    - Mission Operations Center
  - **KSC**
    - Launch services
  - **International Contributions and participation in Instrument Suite and science investigations**

- Austria	- Switzerland
- France	- Finland
- Sweden	- Denmark
- Japan	

MMS Project Organization

Magnetospheric Multiscale (MMS) Project

461-PROJ-REF-0133

MMS Project Manager – C. Tooley
Deputy Project Manager – B. Robertson
Deputy Project Manager/ Technical – V. Moran
Deputy Project Manager/ Resources – W. Sluder
461

- **Risk Mgmt.** – K. Queen

Project Scientist – T. Moore (670)
Deputy Proj.Scientist – M. Adrian / G. Le

Southwest Research Institute (SwRI)
Principal Investigator – J. Burch
Deputy PI – R. Torbert
Instrument Suite Manager – R. Black

- **FIELDS** – R. Torbert
- **FPI** – C. Pollock
- **HPCA** – D. Young
- **EPD** – B. Mauk
- **ASPOC** – K. Torkar
- **CIDP** – M. Epperly
- **CIDP FSW** – A. Bertrand
- **I & T** – A. Henry
- **SOC - Science** – D.N. Baker
- **Systems** – S. Pope
- **T & M** – M. Hesse
- **SMA** – J. Gerhardus
- **Planning** – B. Harbaugh
- **Financial** – M. Breslof

Instrument Systems Manager – R. Borelli

- **Instr. Systems** – D. Jeyasunder, W. Davis, F. Snow

Mission Systems Mgr. – P. Spidaliere (599)
Deputy Systems Mgr. – K. Brenneman

- **S / C Systems** – G. Davis, S. Andrews
- **Systems** – J. McCarthy
- **Avionics** – N. Haghani
- **Contamination** – T. Errigo
- **Elect. Systems** – G. Won
- **GN & C** – W. Morgenstern, O. Hsu
- **Flight Dynamics** – C. Schiff
- **Requirements** – C. Strayhorn-Pelle
- **Mechanical Systems** – D. Hewitt
- **SW Systems** – J. Ong

Chief Safety and Mission Assurance Officer – J. Blackwood (324)

- **Quality Engineer** – M. Swenton
- **EEE Parts** – M. Proctor
- **Radiation** – M. Xapsos
- **Reliability** – T. Pires
- **Systems Safety** – A. Melito
- **Materials** – K. Hodges
- **Software QE** – A. Dasti
- **Perf. Assurance Engrs.** – G. Bertholdt, K. Jackson

Contracting Officer – J. Janus (210)

- **Contract Specialist** – N. Lindon

Financial Manager – M. Gosselin

- **Sr. Resource Analysts** – M. Crespo-Ramos / D. Fennell
- **Resource Analysts** – V. Hernández / D. Perry-Jordon
- **Earned Value Management** – R. Quigley

Sr. Project Support Manager – K. Opperhauser

- **General Business** – K. Higgins / S. Helms
- **Schedule Management** – M. Lilly / R. Miller / D. Wicks
- **Configuration / Data Management** – T. Hegarty / L. Kearney / L. Sullivan / T. Thomas
- **Video Imaging & Photo. Rqmnts** – B. Lambert
- **Information Technology** – C. Jorgensen

Ground Systems Mgr. – S. Coyle (581)
Deputy GS Manager – H. Tann

- **MOM/MOC** – C. Silva
- **SOC - Management** – C. Pankratz
- **Flt. Dynamics/FDOA** – C. Schiff
- **MRT Lead** – S. Jones

Observatory Manager – R. Alemán (500)
Deputy Observ. Mgr. – W. Potter
I & T Manager – J. Baker

- **ACS** – S. Placanica
- **C & DH** – D. Raphael
- **Engine Valve Dr.** – R. Gheen
- **Communications** – A. Rodriguez-Arroyo
- **Flight Software** – M. Walters
- **Harness** – G. Won
- **LV Integration** – K. Hughes
- **Mechanical** – K. Harris
- **Mechanisms** – J. Sturm
- **Navigator** – K. McCaughey
- **Power** – R. Arocho
- **Propulsion** – E. Cardiff
- **Thermal** – N. Teti

06/22/2011

Original Signed By:

Craig Tooley — Date
Magnetospheric Multiscale (MMS) Project Manager

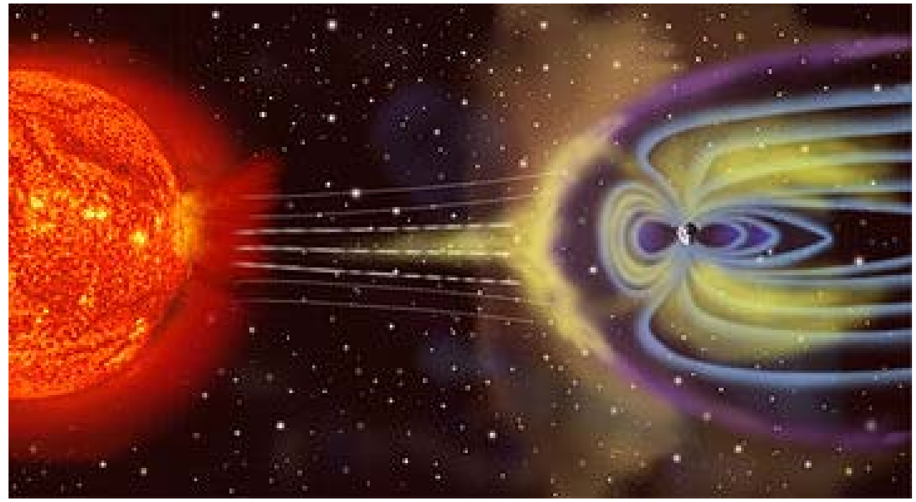
MMS Background- The Magnetosphere

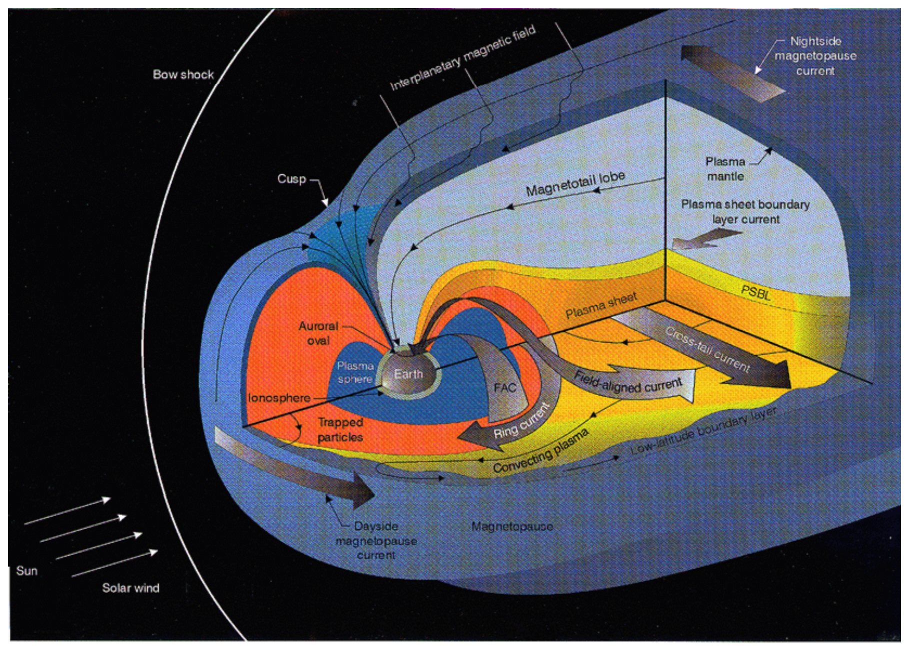
- The **magnetosphere** of Earth is a region in space whose shape is determined by the Earth's internal magnetic field, the solar wind plasma, and the Sun’s interplanetary magnetic field. The boundary of the magnetosphere ("magnetopause") is roughly bullet shaped, about 15 Earth Radii (RE) abreast of Earth and on the night side (in the "magnetotail" or "geotail") approaching a cylinder with a radius 20-25 RE. The tail region stretches well past 200 RE.

- Activity in the magnetosphere causes auroras near the Earth’s poles

- The interaction of the Earth and Solar activities (Space Weather) and can affect satellites, astronauts, and terrestrial power grids and communication systems.

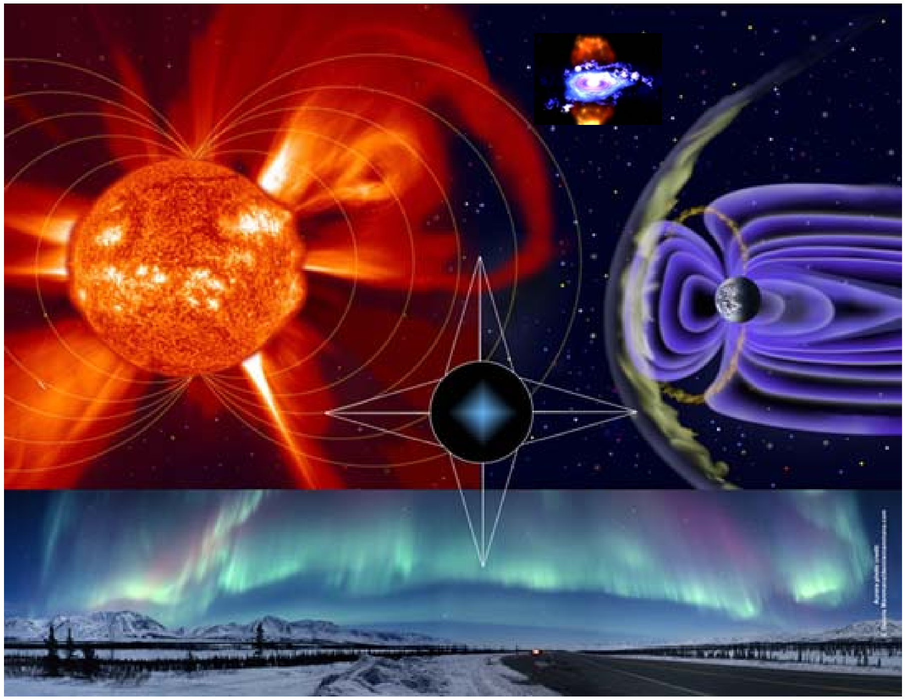
- Earth’s magnetosphere protects the ozone layer from the solar wind. The ozone layer protects the Earth (and life on it) from dangerous ultraviolet radiation





Magnetospheric Multiscale Mission

MMS Objective: ***Finding out how Magnetic Reconnection works***



Magnetic Reconnection:

•**connects and disconnects** plasma regions and taps energy stored in their magnetic fields, converting it into flow acceleration and heat

•**unleashes** explosive phenomena from solar flares to auroras to high-energy cosmic rays to x-ray emissions from accretion disks and fusion plasmas

•**drives** severe "space weather" impacting communications, navigation, power grids, spacecraft and astronaut health and safety

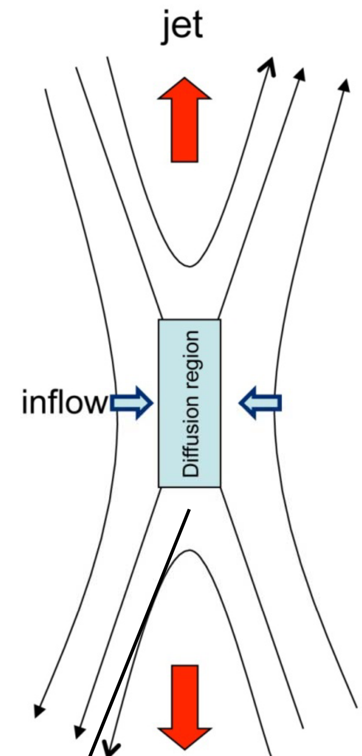
•**reduces** the performance of fusion reactors- an obstacle for achieving fusion power on earth

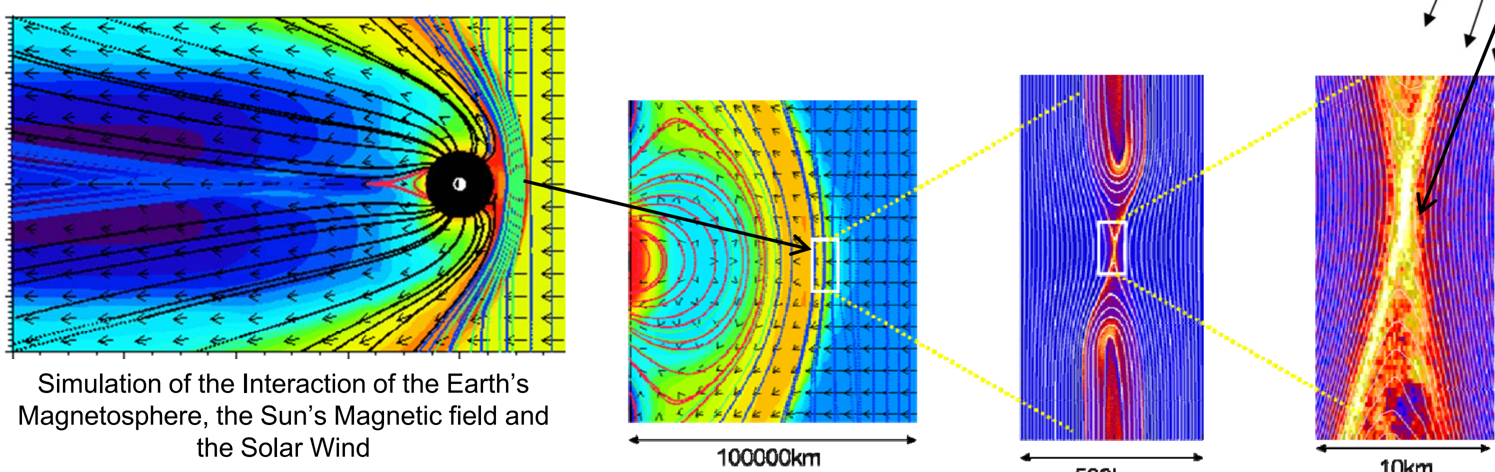
•**impossible** to create on a significant scale on earth, our magnetosphere is the closest laboratory

Solving magnetic reconnection will unlock understanding of a fundamental and universal energetic plasma process that affects and limits our use of technologies on Earth

What is Magnetic Reconnection?

- <u>Magnetic Reconnection is a Fundamental Universal Process</u>
  - Magnetic Reconnection is an energy transfer mechanism of enormous magnitude that is occurring in our near-space environment as well as throughout the universe. *It's physics are not fully understood.*
    - Magnetic fields pointing in opposite directions in a plasma tend to annihilate each other in a diffusion region, releasing their magnetic energy and heating the charged particles in the surrounding environment.
    - The fast release of magnetic energy requires that oppositely pointing magnetic fields be torn apart and reattached to their neighbors in a cross-linking process called magnetic reconnection.

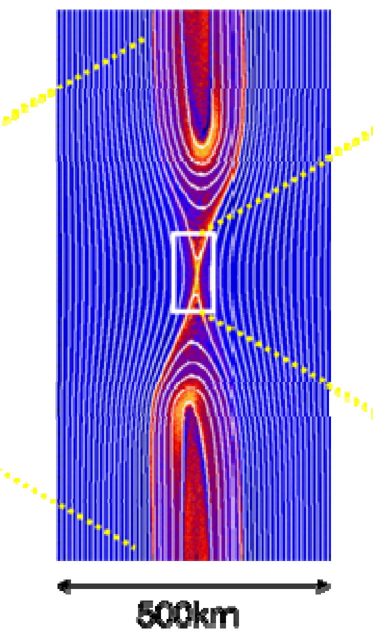


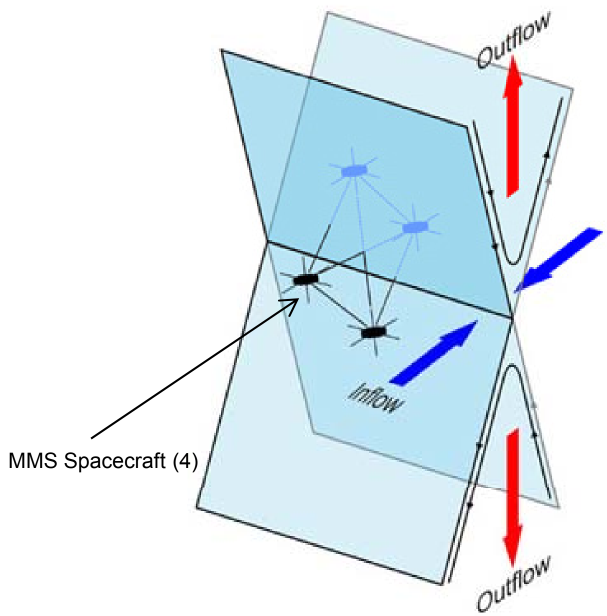


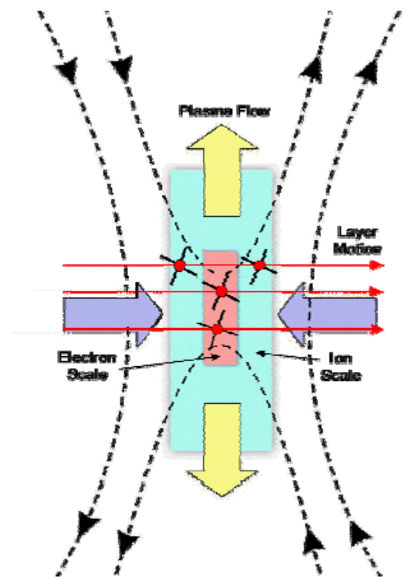
Simulation of the Interaction of the Earth's Magnetosphere, the Sun's Magnetic field and the Solar Wind

How MMS Probes Magnetic Reconnection in the Earth's Magnetosphere

- Repeatedly fly through regions where reconnection occurs (regions-of-interest)
- Detect and measure reconnection events, *which are not stationary continuous events*
  - Energetic particles (electron & ions) abundance and behavior
  - Electric field strength and variation with time
  - Magnetic field strength and variation with time
- Make measurement in 3 dimensions – thus 4 spacecraft
- Make measurements quickly as events are short - resolution for electron diffusion region is ≤ 30 mseconds
- Fly the 4 spacecraft in close formation (10-100km separations) as events are highly localized
- Collect data continuously in regions-of-interest but only downlink high resolution data likely to be from a reconnection event, ~ 4 Gbits/day. Far too much data will be collected onboard to downlink it all.

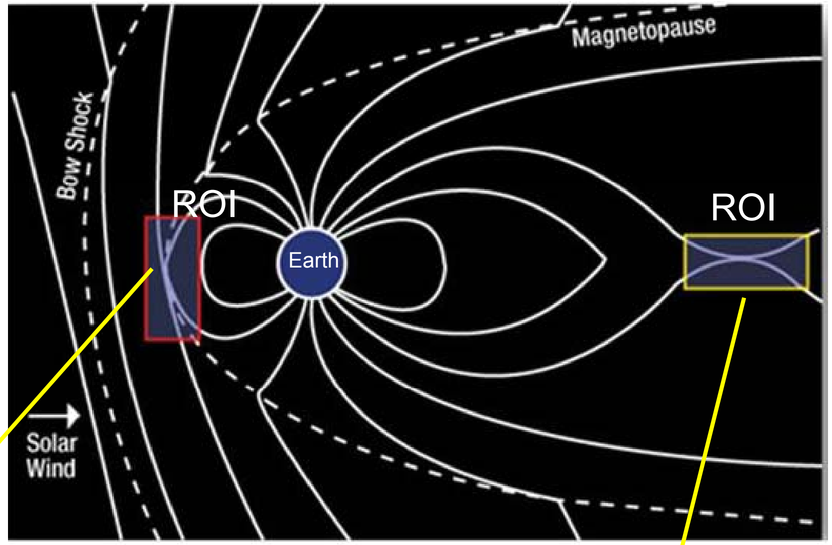


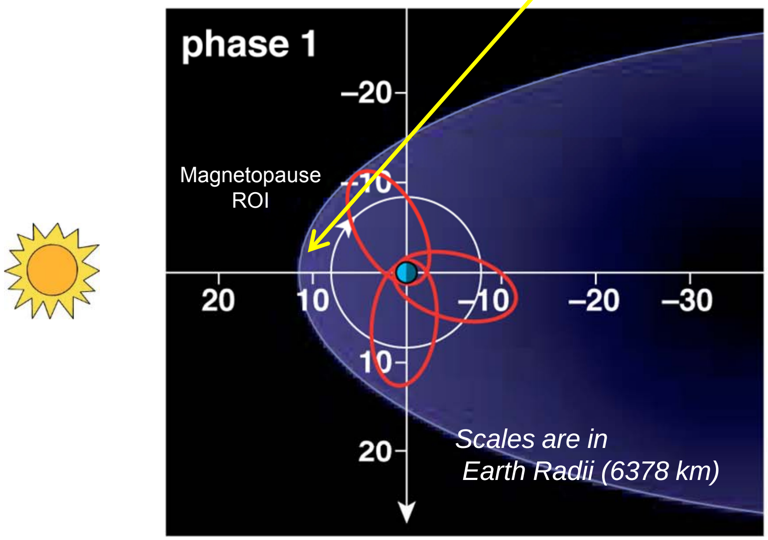


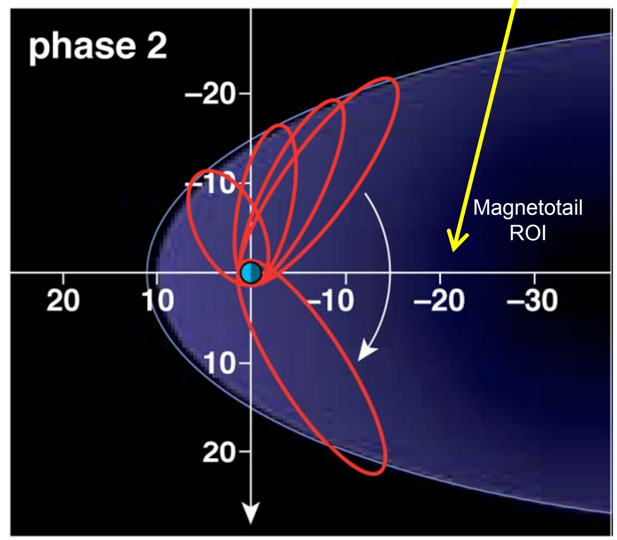


Flying MMS- Orbits & Regions Of Interest (ROI)

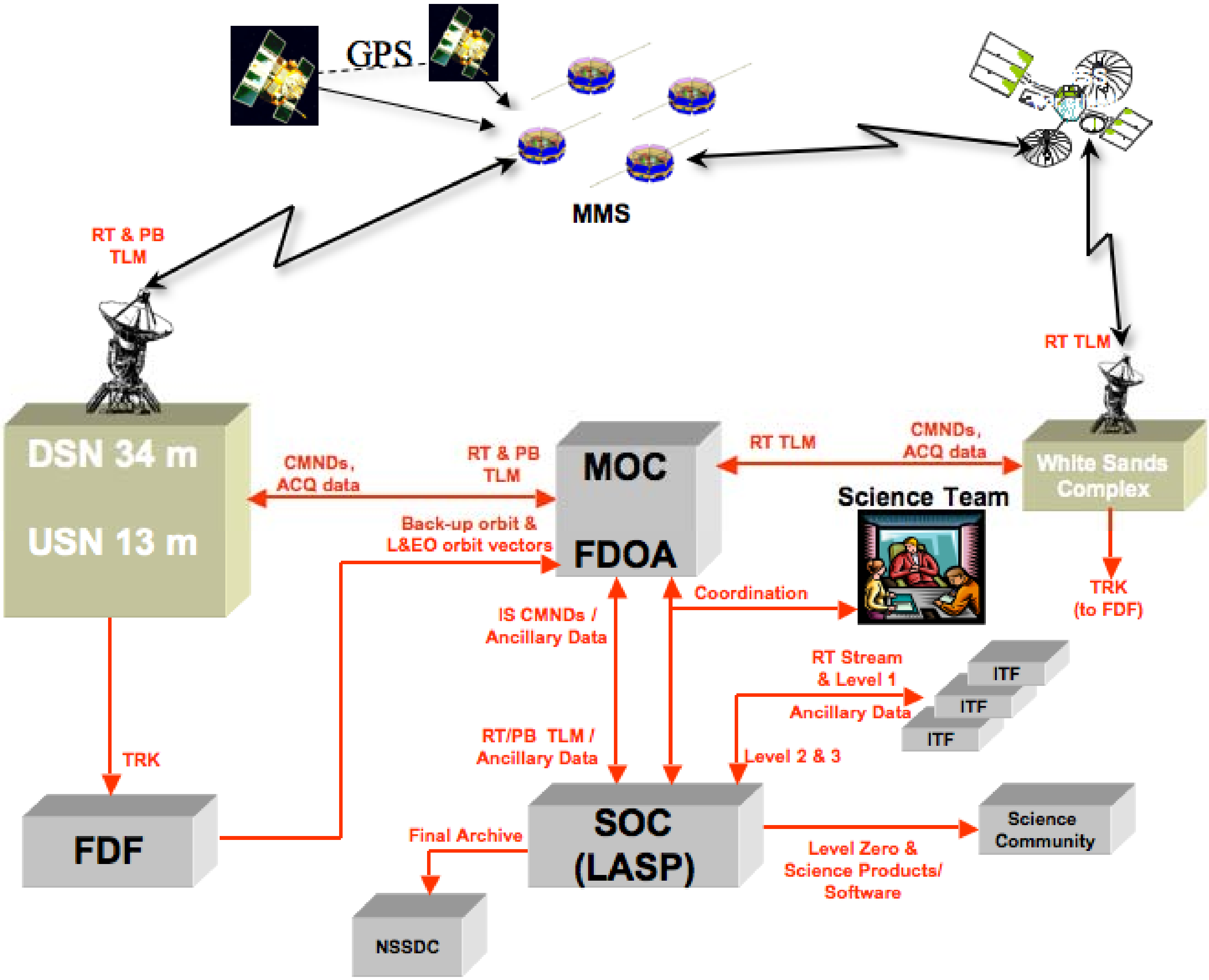
- The 4 MMS Observatories are launched into a elliptical orbit (red) which moves through the magnetopause boundary ROI as the Earth orbits the Sun.
- MMS Observatories will be maneuvered into a higher orbit the second year which will pass thru the magnetotail ROI
- On-board GPS and ground tracking data will be used in conjunction with closed-loop maneuver executions to maintain required spacecraft tetrahedron formations.



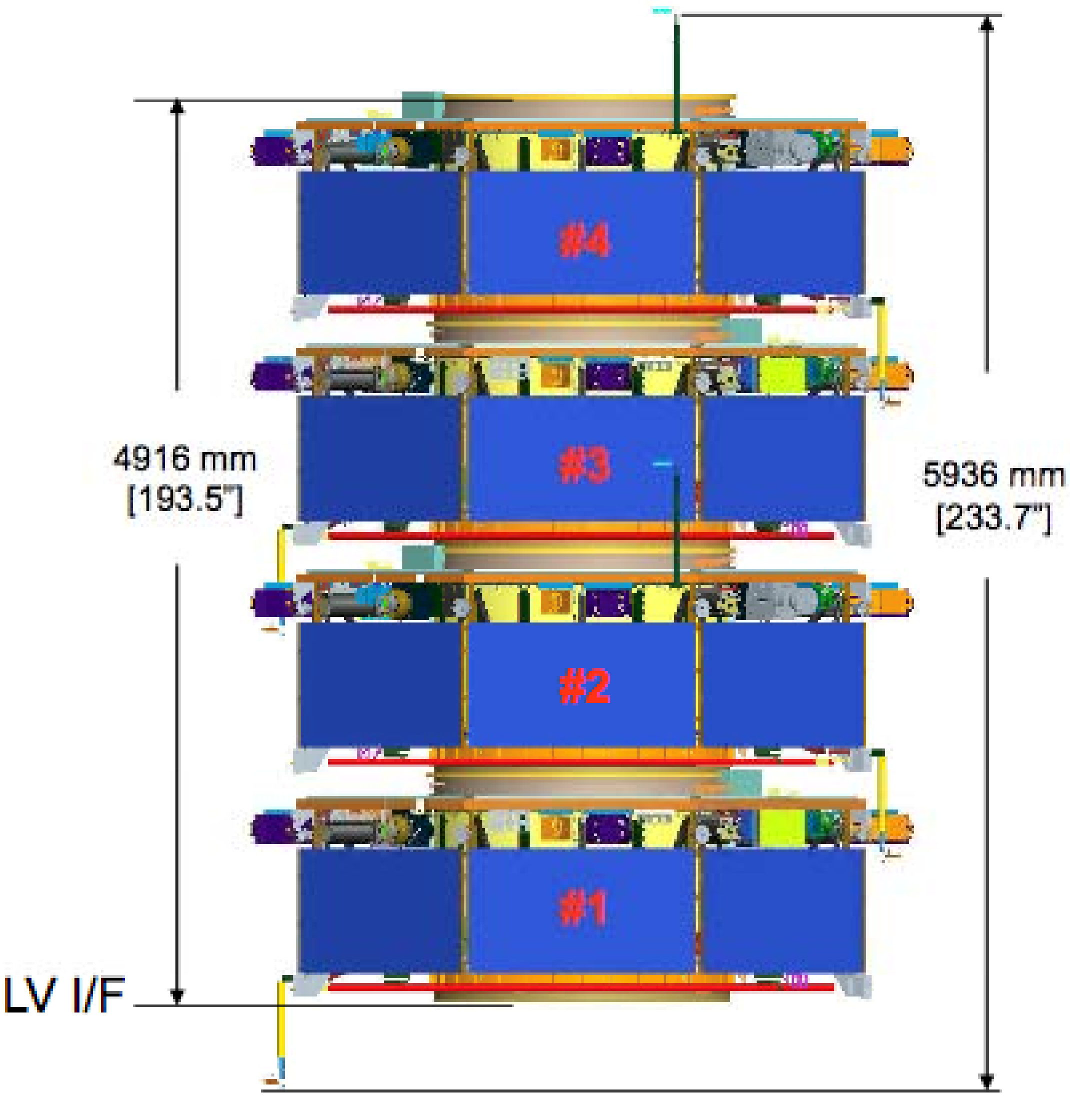


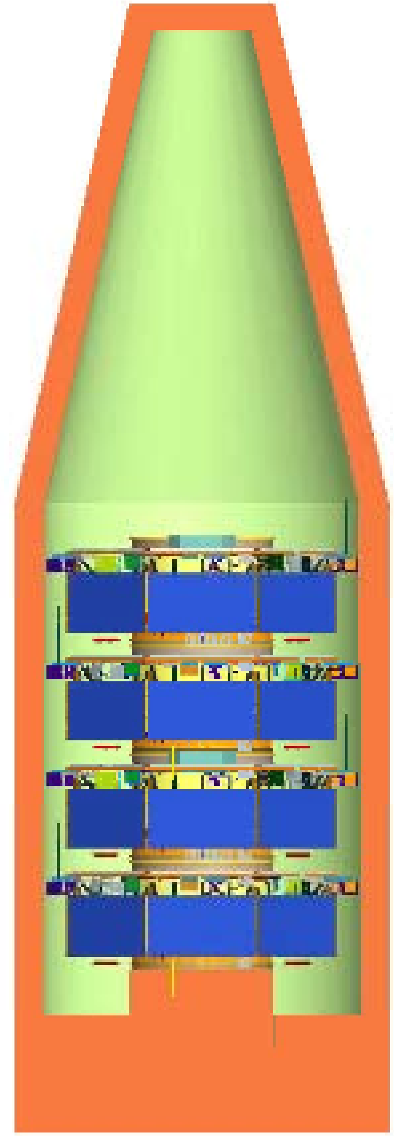


Flying MMS - Ground System Architecture

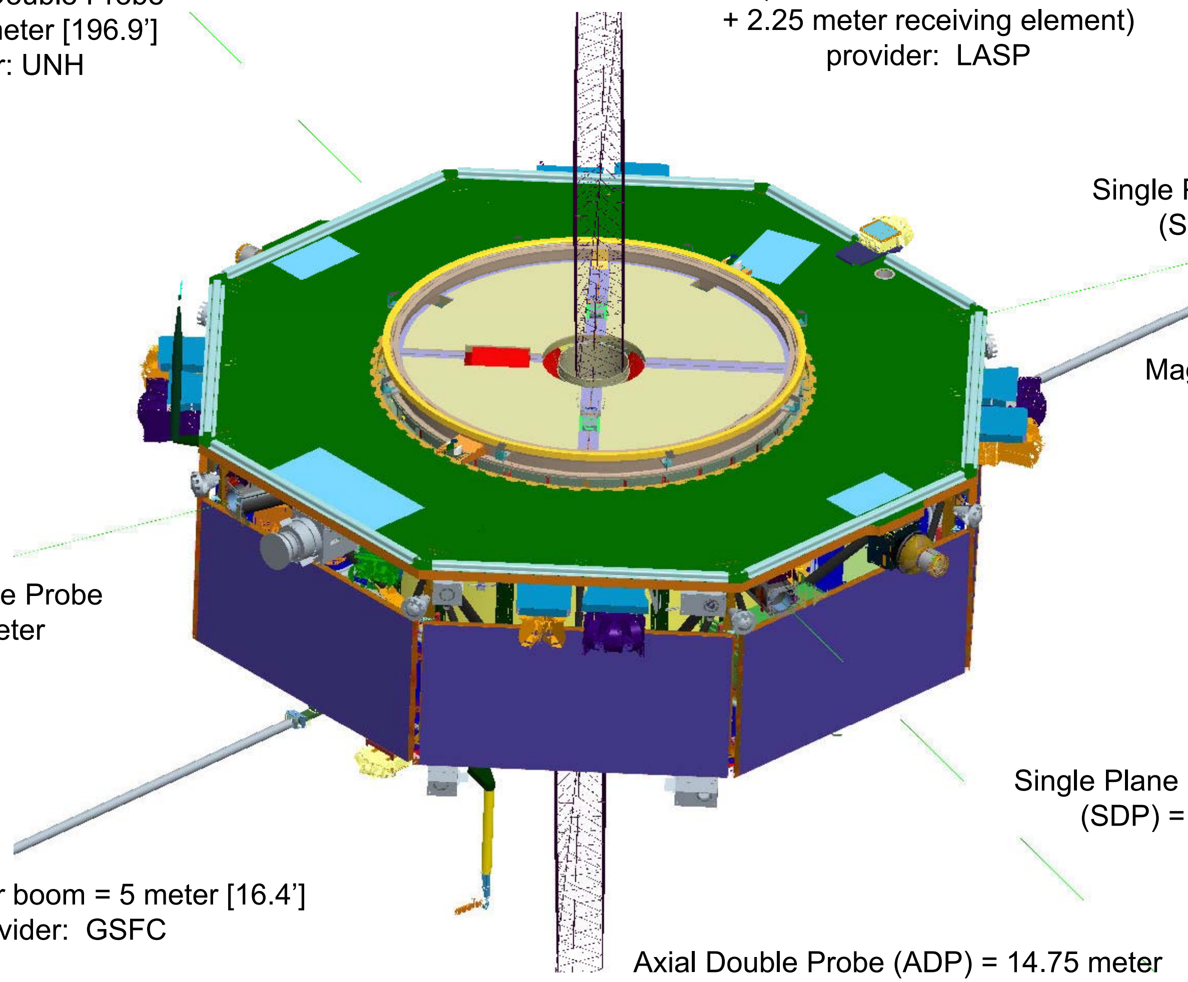


MMS Observatories Stacked in Atlas-V Rocket Fairing

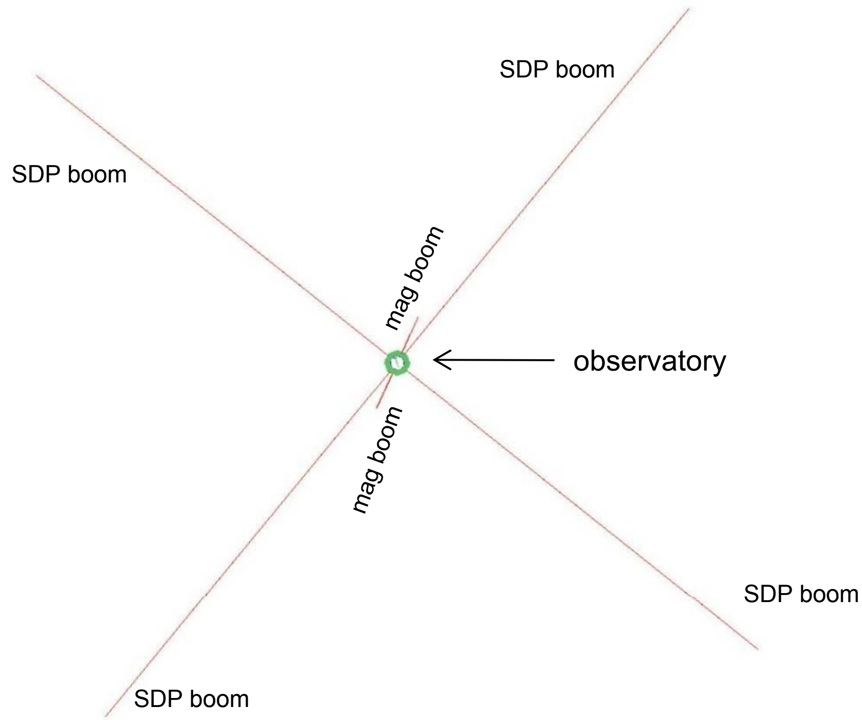


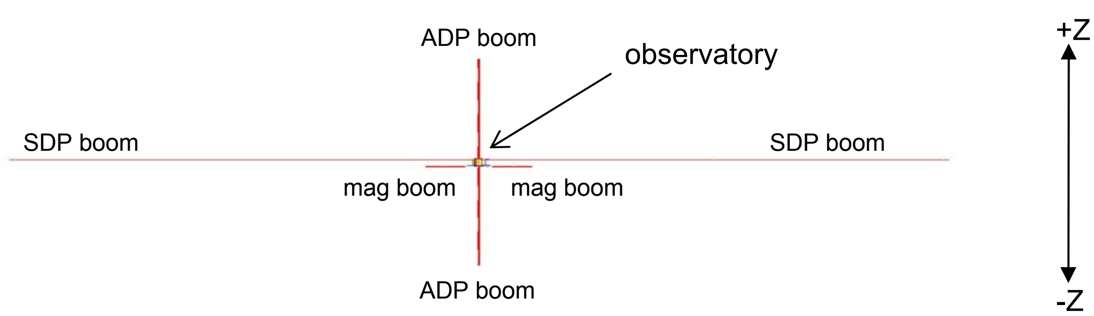


MMS Observatory - Deployed

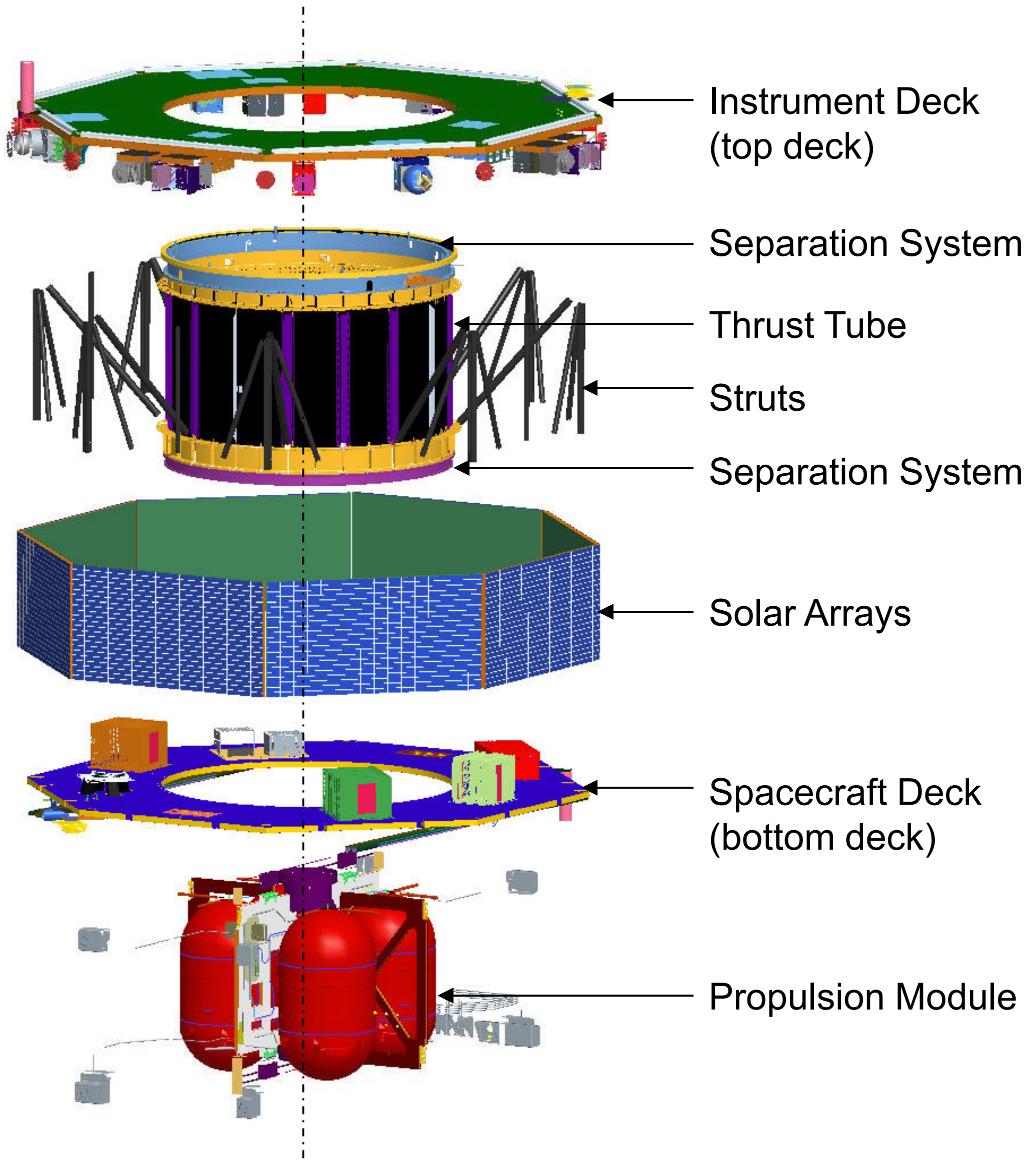


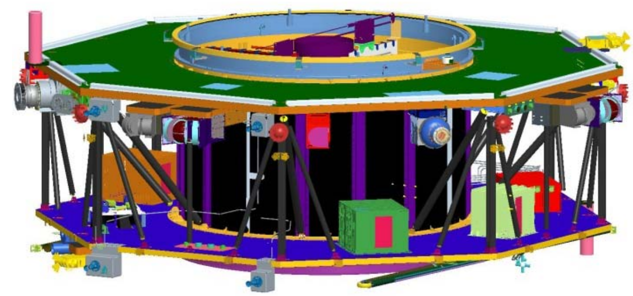
Deployed MMS Observatory – to scale

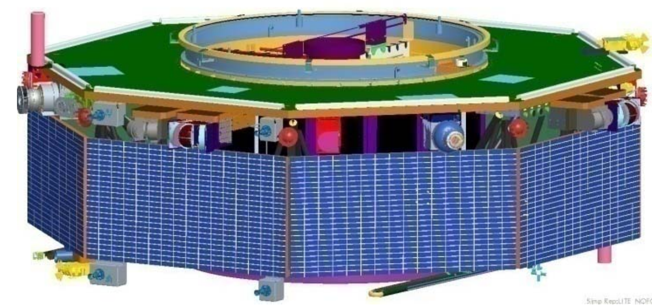




MMS Observatory Layout

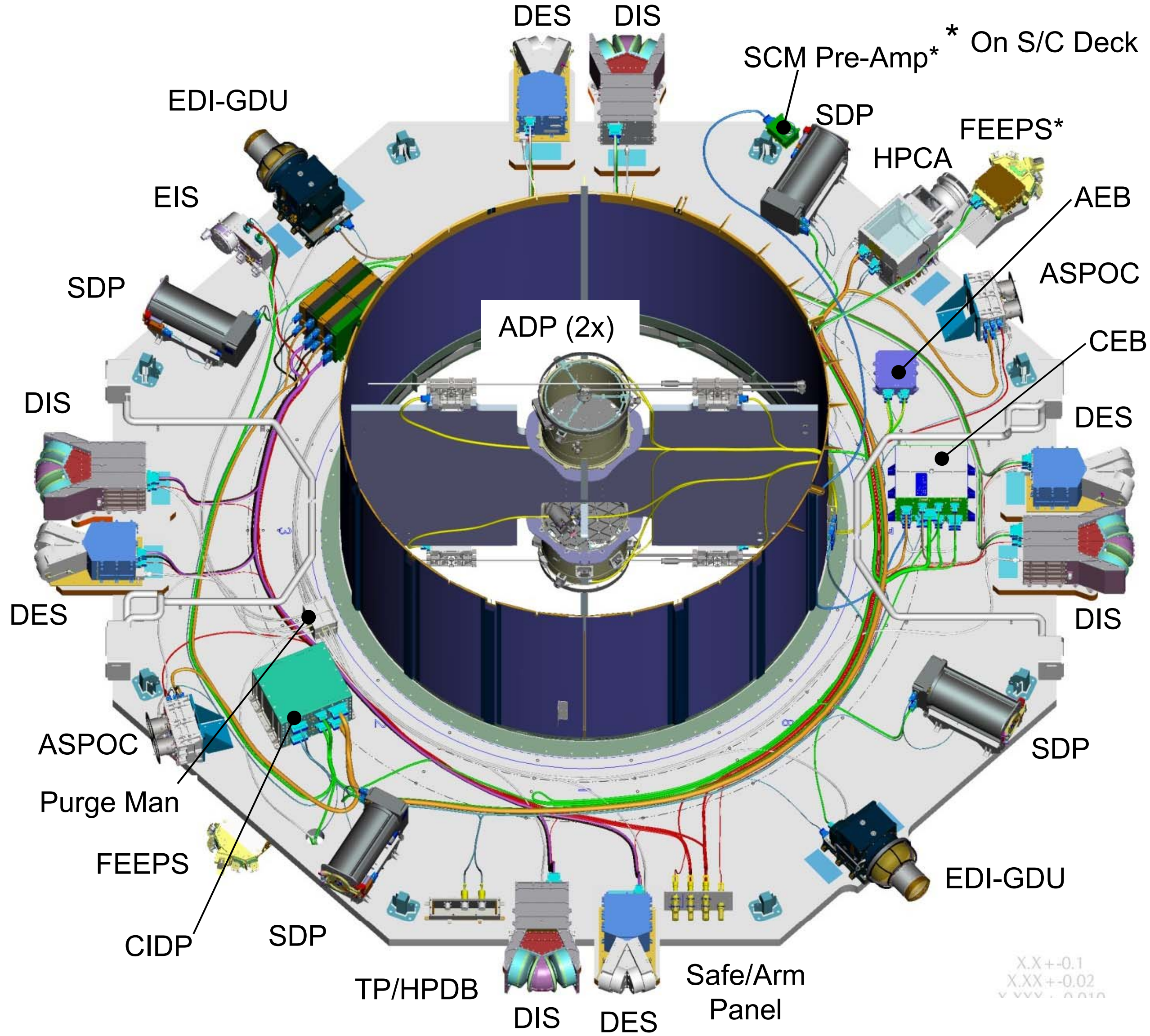






MMS Instrument Suite Components

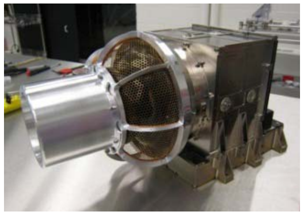
(view looking from the bottom of the IS Deck)



ADP - Axial Double Probe
AFG - Analog Flux Gate Magnetometer (mounted on boom)
ASPOC - Active Spacecraft Potential Control
CEB - Central Electronics Box (Fields)
CIDP - Central Instrument Data Processor
DES - Dual Electron Spectrometer
DFG - Digital Flux Gate Magnetometer (mounted on boom)
DIS - Dual Ion Spectrometer
EDI/GDU - Electron Drift Instrument/ Gun Detector Unit
EIS - Energetic Ion Spectrometer
FEEPS - Fly's Eye Energetic Particle Sensors
HPCA - Hot Plasma Composition Analyzer
IDPU - Instrument Data Processing Unit (FPI)
SCM - Search-Coil Magnetometer (mounted on boom)
SDP - Spin-Plane Double Probe
TP/HPDB – Test Panel Heater Power Distribution Box

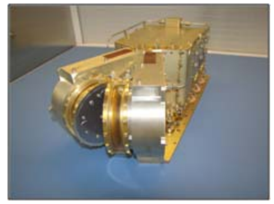
MMS Observatories are Being Built

Fabrication and assembly of flight equipment is in full swing

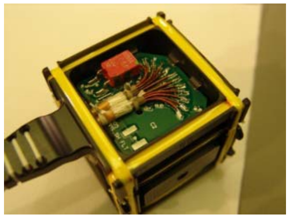

FIELDS EDI ETU

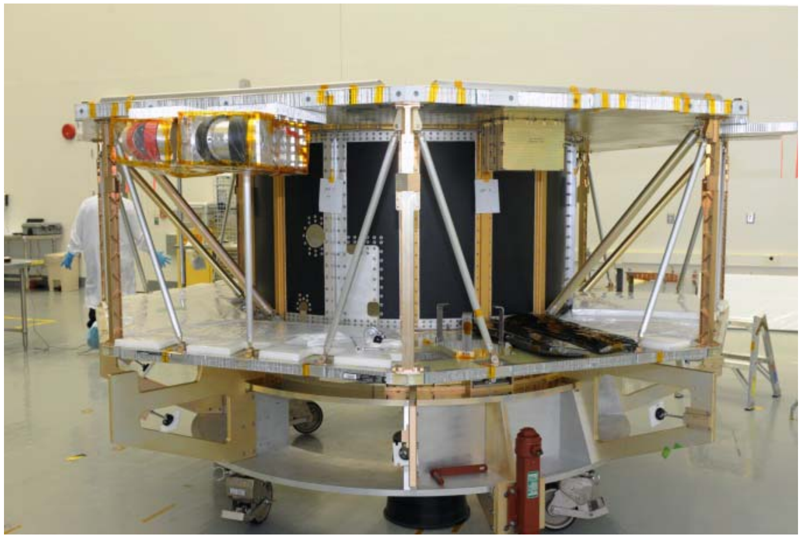

FIELDS ADP FM1


Instrument EM Harness


FPI DES ETU

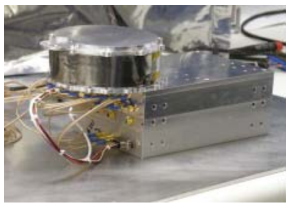

Navigator FLT GPS Antenna


FIELDS DFG Sensor FM1


MMS Observatory Flight Structure #1 with FPI installed during fit-check


C&DH FLT #1 (computer)

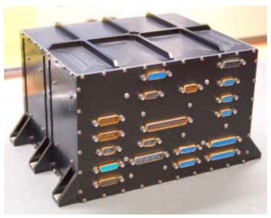

Engine Valve Drive FLT #1


EPD EIS ETU


Power Electronics (PSEES) FLT #1

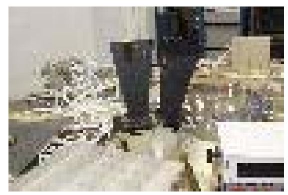

CIDP ETU


FPI DIS ETU


FIELDS CEB ETU

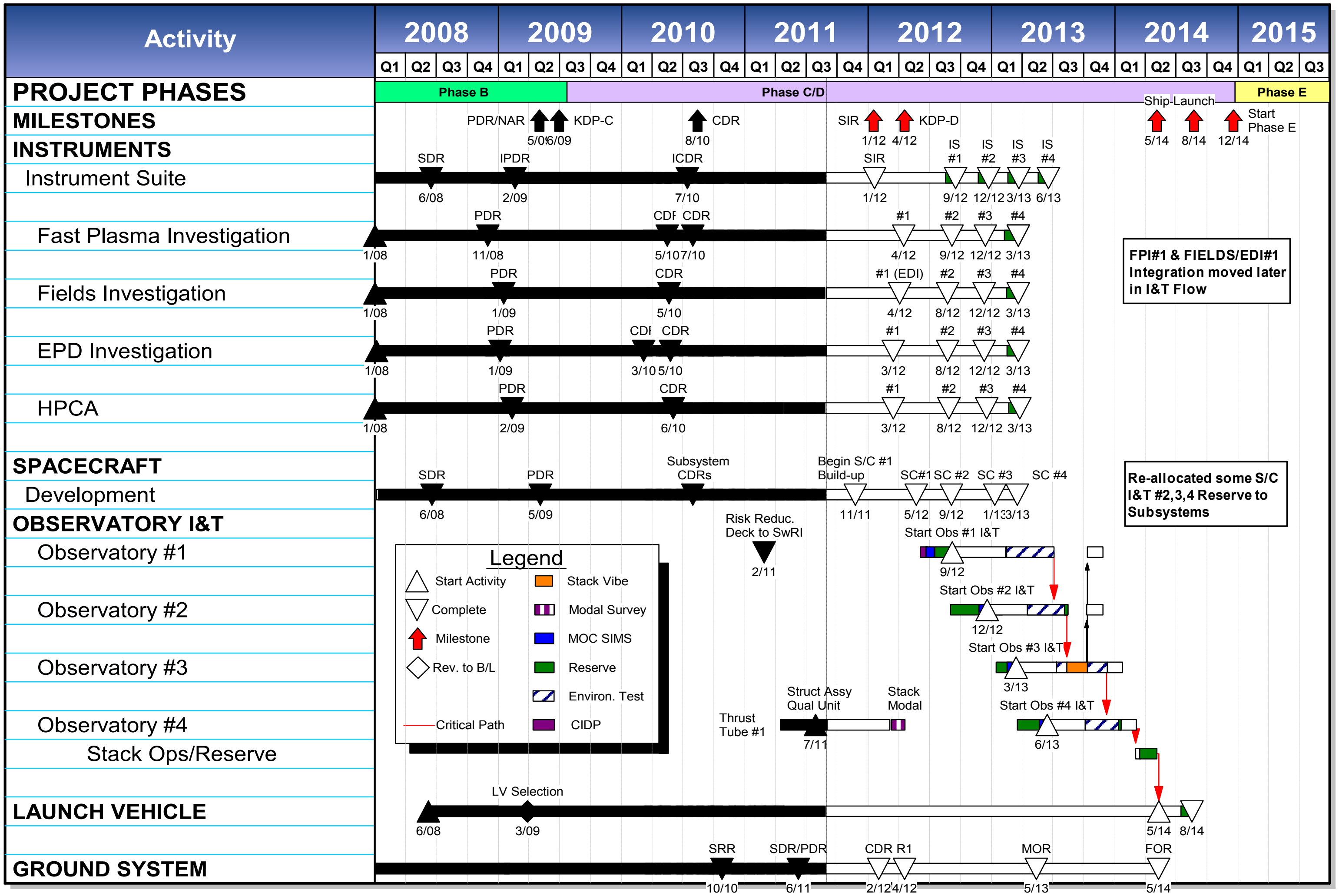

ASPOC ETU


Propulsion System water hammer test


Star Sensors in FlatSat

MMS Master Schedule

Status as of 8/30/11



ATP – Authority to Proceed
AO – Announcement of Opportunity
CDR – Critical Design Review
Dev - Development
DT – Demonstration Test
EPD – Energetic Particle Detection
FOR – Flight Operations Review

HPCA – Hot Plasma Composition
I - Instrument
IS – Instrument Suite
KDP-Key Decision Point
LSTO – Launch Services Task Order
LV – Launch Vehicle
MDR – Mission Definition Review

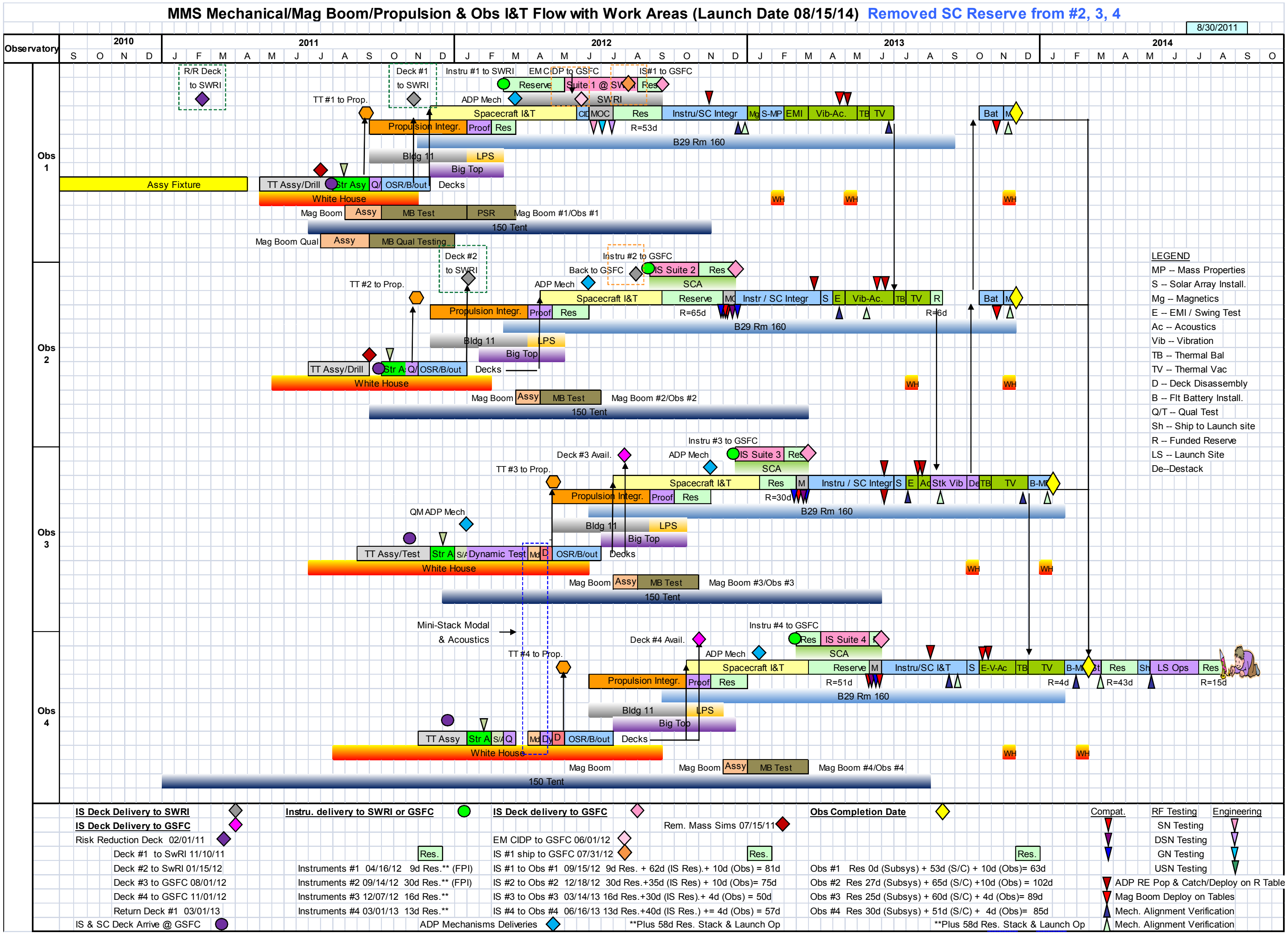
MOC – Mission Operations Center
Mod - Modification
MOR – Mission Operations Review
NAR – Non-Advocacy Review
Obs - Observatory
Ops - Operations
ORR – Operations Readiness Review

PDR – Preliminary Design Review
PER – Pre-Environmental Review
Pre-NAR – Preliminary NAR
PRR – Production Readiness Review
R - Release
RFP – Request for Proposal
SC - Spacecraft

SDR – System Design Review
Sims - Simulations
SIR - System Integration Review
SOC - Science Operations Center
Sp - Spares
SRR - System Requirements Review
STM – Structural Test Model

SwRI-Southwest Research Institute
TVAC – Thermal Vacuum
Obs – Observatory
B/L – Baseline

MMS I&T Schedule



MMS Challenges & Status

- The MMS mission present a number of challenges to NASA, GSFC, and SwRI, many of which are unique to the MMS mission. The key challenges include:
  - MMS requires 4 identical Observatories which will be built, integrated, and test during a single I&T campaign. Each Observatory has 25 instruments, some instruments must build as many as 16 copies.
    - The most complex I&T flow ever performed at GSFC
    - Multiple builds tax the supply chain in ways not typical for GSFC
    - Management of the large number of diverse participants in the instrument development and mission execution is a challenge for both GSFC and SwRI.
  - The precision maneuvering required maintain the orbits and tetrahedron formation of the 4 spinning spacecraft makes this one of the most challenging missions the GSFC Guidance, Navigation and Control group has ever undertaken.
  - MMS communication bandwidth limitations make it necessary to develop methods to store large amounts of data on-board and identify high value data for downlink and allowing overwrite of the remainder before the recorder is full.
    - Requires a combination of automated and human-in-the-loop processes.
    - Science operations will be highly dynamic throughout the mission, i.e. it will never truly calm down to highly routine operations akin to many other missions.
- *GSFC, SwRI and all the MMS Team Members welcome these and the many other challenges the mission entails!*
  - The MMS mission's budget, schedule, and technical posture is healthy
  - MMS is on-track for the planned August 2014 Launch

MMS Risk Management

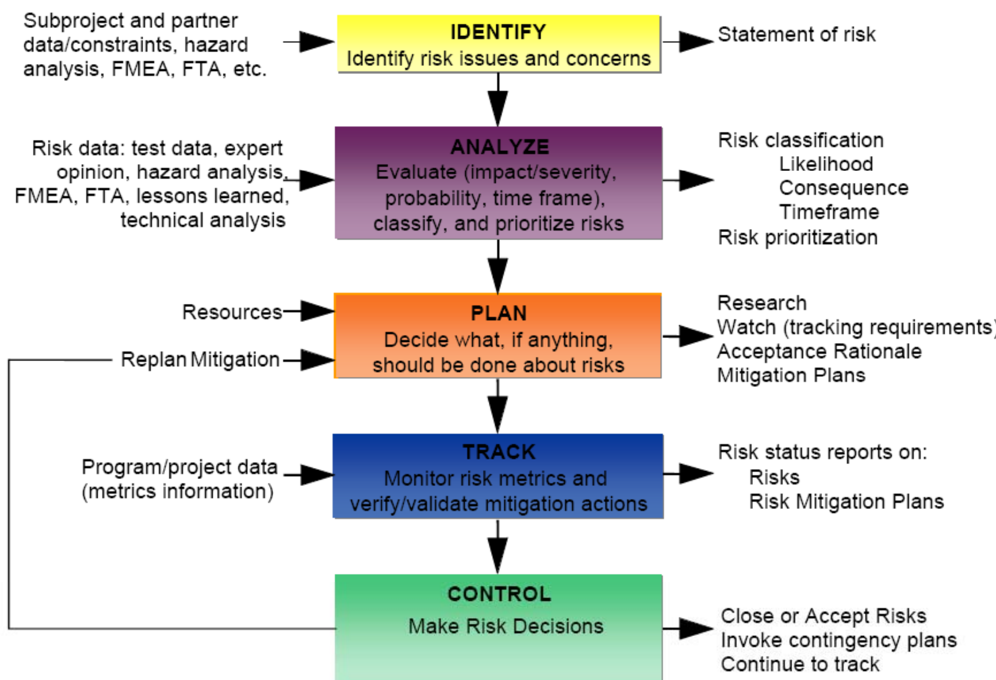
Brent Robertson
MMS Deputy Project Manager

Risks / Issues / Threats

- Risk = the combination of the probability that a project will experience an undesired event and the consequences, impact, or severity of the undesired event, were it to occur
- Issue = a problem that has occurred that requires project resources to fix
- Threat = expected impact to cost and schedule reserves of risks

MMS Risk Management

- MMS utilizes a Continuous Risk Management Approach, as documented in MMS Project Continuous Risk Management Plan (MMS-461-PLAN-0009)
- Fully consistent with:
  - NPR 7120.5D, NASA Space Flight and Project Management Requirements
  - NPR 8000.4, Risk Management Procedural Requirements
  - GPR 7120.4, Risk Management
- Integrated across all MMS Project elements through life cycle of Project



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FMEA – Failure Modes and Effects Analysis
FTA – Fault Tree Analysis

Continuous Risk Management Defining Principles

- Forward-looking View: Projects learn to look beyond today's crisis, and to the current crisis' future consequences
  - Constantly thinking ahead to identify uncertainties; anticipating possible outcomes
  - Allocating project resources and managing activities with an eye on the future
- Shared Product Vision: Project personnel become attuned to the project objectives and the *overall* product it's producing (bigger picture)
  - Common understanding of how each piece integrates to become an Observatory
  - Fosters a shared vested interest in the outcome; mutual commitment
- Global Perspective: People begin to look beyond their specific interests, goals and tasks, reaching a common view of what's important to the project/organization
  - Better understanding of the higher-level systems requirements, design and implementation
  - Clearer appreciation for the scope of potential impacts (ripple effect)

Continuous Risk Management Sustaining Principles

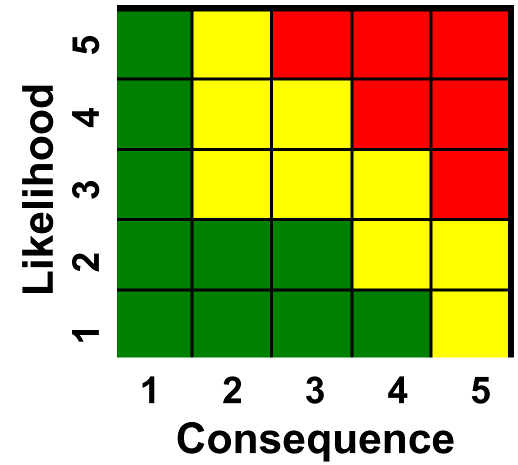
- Integrated Management: Risk Management becomes an integral Project Management tool, consistent with the project culture and philosophy
  - Brings project groups (e.g., science, finance, engineering, operations) together toward a common goal
  - Communicates the project's management vision and philosophy to *all* levels

- Teamwork and Communication: *Entire* project understands all the potential problems, consequences and options
  - Everyone works together as part of a team, toward a common goal
  - Common understanding of project strategy and decision rationale
  - Talent, skills and knowledge are brought together monthly

- Continuous Process: Risk Management becomes a daily activity
  - Project establishes and *sustains* constant vigilance
  - Once established during Formulation, Risk Management becomes routine, continually identifying and managing risk throughout all project life cycle phases

GSFC Risk Matrix Standard Scale

Likelihood	Safety (Estimated likelihood of safety event occurrence)	Technical (Estimated likelihood of not meeting performance requirements)	Cost/Schedule (Estimated likelihood of not meeting cost or schedule commitment)
5 Very High	$(P_{SE} > 10^{-1})$	$(P_T > 50\%)$	$(P_{CS} > 75\%)$
4 High	$(10^{-2} < P_{SE} \leq 10^{-1})$	$(25\% < P_T \leq 50\%)$	$(50\% < P_{CS} \leq 75\%)$
3 Moderate	$(10^{-3} < P_{SE} \leq 10^{-2})$	$(15\% < P_T \leq 25\%)$	$(25\% < P_{CS} \leq 50\%)$
2 Low	$(10^{-6} < P_{SE} \leq 10^{-3})$	$(2\% < P_T \leq 15\%)$	$(10\% < P_{CS} \leq 25\%)$
1 Very Low	$(P_{SE} \leq 10^{-6})$	$(0.1\% < P_T \leq 2\%)$	$(P_{CS} \leq 10\%)$



HIGH RISK

MODERATE RISK

LOW RISK

Consequence Categories					
Risk	**1 Very Low**	**2 Low**	**3 Moderate**	**4 High**	**5 Very High**
Safety	Negligible or No impact.	Could cause the need for only minor first aid treatment .	May cause minor injury or occupational illness or minor property damage.	May cause severe injury or occupational illness or major property damage.	May cause death or permanently disabling injury or destruction of property.
Technical	No impact to full mission success criteria	Minor impact to full mission success criteria	Moderate impact to full mission success criteria. Minimum mission success criteria is achievable with margin	Major impact to full mission success criteria. Minimum mission success criteria is achievable	Minimum mission success criteria is not achievable
Schedule	Negligible or no schedule impact	Minor impact to schedule milestones; accommodates within reserves; no impact to critical path	Impact to schedule milestones; accommodates within reserves; moderate impact to critical path	Major impact to schedule milestones; major impact to critical path	Cannot meet schedule and program milestones
Cost	<2% increase over allocated and negligible impact on reserve	Between 2% and 5% increase over allocated and can handle with reserve	Between 5% and 7% increase over allocated and can not handle with reserve	Between 7% and 10% increase over allocated, and/or exceeds proper reserves	>10% increase over allocated, and/or can't handle with reserves

Code 300
Rev. 021307

MMS Risk Management

- MMS Risk Management process is built around significant participation by the functional teams, instrument providers, suppliers and other affiliated organizations; process encourages *all* team members to identify risks
- Assumption that the expertise required to identify, rank, prioritize, and develop mitigation strategy typically resides at the "grass-roots" level (individual team members)
- Open communication of risks is encouraged at all project levels
- All risks are tracked on a monthly basis by the MMS Risk Management Board (RMB), comprised of MMS Senior Staff and Product Development Leads (as req.) until retired
- RMB adjusts mitigation activities and resource assignments monthly

Risk Management Benefits & Cost

- Benefits:
  - Prevents Problems Before They Occur – Identifies potential problems and addresses them early, when it is easier and cheaper to do so
  - Improves Product Quality – Keeps team focused on the project's objective and consciously looking for things that could degrade quality
  - Promotes Teamwork – Involves people at all project levels and focuses their attention on a shared product vision

- Costs:
  - Infrastructure Costs – Cost associated with establishing and maintaining the risk management process within a project or organization
  - Risk Management Costs – Cost associated with conducting risk management activities within a project or organization
  - Mitigation Costs – Cost associated with mitigating risks

MMS Risk Management: How to Measure Success?

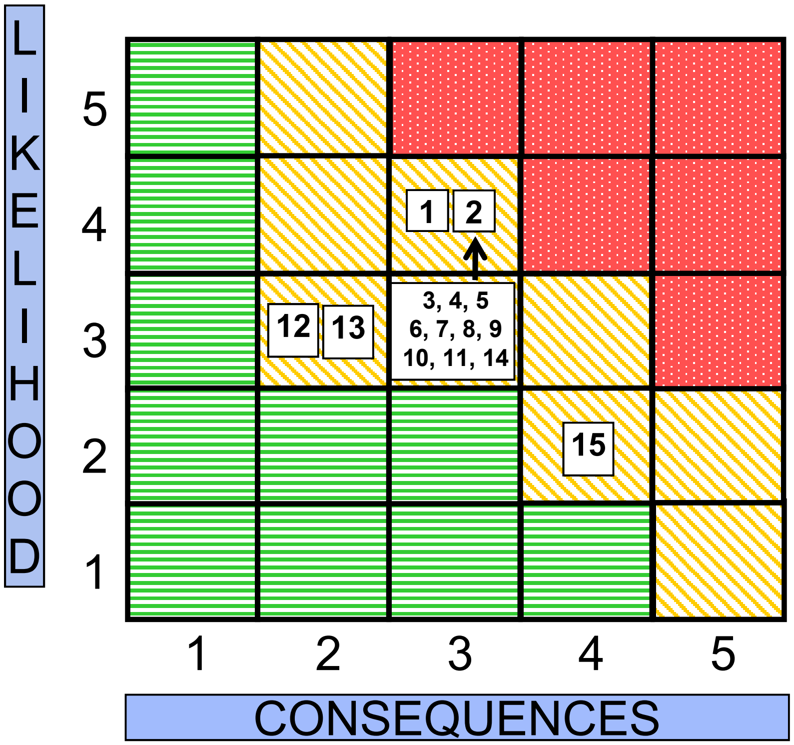
- How many risks were mitigated before becoming issues or mishaps?
- How much was Product Quality improved by keeping the team focused on the project's objective and consciously looking for things that could degrade quality?
- How much was Teamwork enhanced by involving people at all project levels and focuses their attention on a shared product vision?
- Were appropriate resources allocated for Infrastructure, Risk Management and Mitigation costs?
- How many issues were encountered that were not identified or tracked as risks?
- How many risks were identified late, when mitigation was costly?

MMS Issues

- MMS Project has reported 19 issues to date
- Most costly issues have been caused by GSFC Facility Conflicts, EEE Parts, Board Manufacturing, Component Development and Instrument Development
- More than one issue was caused by vendors encountering quality problems when ramping up production to meet the large number of quantities required by MMS
- Some issues were predicted by risks; others were not anticipated

Issue	Category	Element
Preliminary KDP-C Cost Estimate Exceeds Cost Cap	Cost/Schedule	Project Budget
FIELDS KTH Ability to Deliver SDP	Cost/Schedule	Contributed Instrument
I&T Clean Room	Cost/Schedule	GSFC Facility
FPI A111 Preamp Dynamic Range	Technical	EEE Part
Amptek HV801 Optocoupler Failures	Technical	EEE Part
Avionics Board Manufacturing	Cost/Schedule	Board
FPI Cost Overrun	Cost/Schedule	Instrument
Low FY11 Cost Reserves	Cost/Schedule	Project Budget
Accelerometer Shock	Technical	Component
Instrument Suite Power Increase	Technical	Instrument Suite
Low FY12 Cost Reserves	Cost/Schedule	Project Budget
Navigator ETU Completion	Cost/Schedule	In-house Component
C&DH to CIDP Communication	Technical	Observatory
Iridite Coating Quality Problems	Technical	Mechanical Parts
S-Band Antenna Failure in Vibration Testing	Technical	In-house Component
HPCA Cost	Cost/Schedule	Instrument
Civil Service Labor Re-pricing	Cost/Schedule	Project Budget
Micropac Opto-FET Failures	Technical	EEE Part
Gravity Gradient Disturbance	Technical	Systems Engineering

MMS Project Top Risks



LxC Trend	Rank	Risk ID	Approach	Risk Title
→	1	274	M	Launch Opportunities
↑	2	301	M	Environmental Test Facility Conflict
→	3	291	M	FPI Cost Increase/Schedule
→	4	303	M	I&T Schedule
→	5	300	M	Manufacturing Delays
→	6	83	M	Sparing Philosophy
→	7	182	M	I&T Staffing
→	8	95	M	Maneuver Execution Accuracy
→	9	309	M	Multiple Build Rework
→	10	285	M	EDI Schedule/Gun Focus
→	11	311	M	Phase E Cost
→	12	242	M	Institution Facility/Cost
→	13	261	`M	Clean Room Completion Schedule
■	14	319	M	HPCA
→	15	316	M	AMS Accelerometer Sensor Reliability

Criticality	L & C Trend	Approach
High	↓ Decreasing (Improving)	M - Mitigate
Med	↑ Increasing (Worsening)	W - Watch
Low	→ Unchanged	A - Accept
	■ New Since Last **MSR**	R - Research

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MMS Risk Based Threats Analysis

- Total threat to MMS Cost Reserve & Schedule Reserve is estimated monthly using a probabilistic weighting of all cost/schedule risks

($ values for each risk not shown on this slide)

MMS Cost/Schedule Risks - $K 10/5/2011

Risk ID	Risk Title	Risk Consequence	Risk Likelihood	FY12	FY13	FY14	FY15 +	Total	Schedule Impact (days)	Probability	FY12	FY13	FY14	FY15 +	Total	Expected Schedule Impact (days)	Critical Path Impact (days)
274	Launch Opportunities	3	4							0.60	$ -	$ -	$ -	$ -	$ -	0	
301	Environmental Test Facility Conflict	3	4						20	0.60	$ -	$ -	$ -	$ -	$ -	12	12
291	FPI Cost Increase / Schedule	3	3						20	0.40	$ -	$ -	$ -	$ -	$ -	8	8
303	I&T Schedule	3	3						40	0.40		$ -	$ -	$ -	$ -	16	16
300	Manufacturing Delays	3	3						30	0.40	$ -	$ -	$ -	$ -	$ -	12	12
83	Sparing Philosophy	3	3						15	0.40	$ -	$ -	$ -	$ -	$ -	6	6
182	I&T Staffing	3	3						20	0.40	$ -	$ -	$ -	$ -	$ -	8	8
309	Multiple Build Rework	3	3						20	0.40	$ -	$ -	$ -	$ -	$ -	8	8
311	Phase E Cost	3	3							0.40	$ -	$ -	$ -	$ -	$ -	0	
285	EDI Schedule	3	3						20	0.40	$ -	$ -	$ -	$ -	$ -	8	
319	HPCA Cost/Schedule	3	3						10	0.40	$ -		$ -	$ -	$ -	4	
242	Institutional / Facility Costs	2	3							0.40	$ -	$ -	$ -	$ -	$ -	0	
					Total Yellow Risk Expected Cost Reserve Impact ($K)						**$ 3,090**	**$ 3,760**	**$ 5,140**	**$ 5,200**	**$ 17,190**		
					Total Yellow Risk Expected Schedule Reserve Impact (days)												**70**
321	Civil Service Labor Repricing	3	2							0.20	$ -	$ -	$ -	$ -	$ -	0	
262	SDP Delivery Schedule	3	2						15	0.20	$ -	$ -	$ -	$ -	$ -	3	
302	Manufacturing/Test/Analysis Cost Increase	3	2							0.20	$ -	$ -	$ -	$ -	$ -	0	
304	Design Changes	3	2						20	0.20	$ -	$ -	$ -	$ -	$ -	4	
252	Card Manufacturing	3	2						20	0.20	$ -	$ -	$ -	$ -	$ -	4	
320	CIDP Cost/Schedule	2	2						10	0.20	$ -	$ -	$ -	$ -	$ -	2	
318	Flight Batteries	2	2						13	0.20		$ -	$ -	$ -		3	3
317	Iridite Coating	2	2						20	0.20	$ -	$ -	$ -	$ -	$ -	4	4
289	ASPOC Schedule	2	2						20	0.20	$ -	$ -	$ -	$ -	$ -	4	
279	Propulsion Line Clearance	2	2						10	0.20	$ -	$ -	$ -	$ -	$ -	2	
282	Contract Termination Liability	2	2						10	0.20	$ -	$ -	$ -	$ -	$ -	2	
292	Mag Boom Hardware Delivery Schedule	2	2						20	0.20	$ -	$ -	$ -	$ -	$ -	4	
205	University/Subcontractor QA Program	2	2						10	0.20	$ -	$ -	$ -	$ -	$ -	2	
269	TDRS Extended Field Of View	2	2							0.20	$ -	$ -	$ -	$ -	$ -	0	
290	Ground Ops & Launch Site Cooling	2	2						2	0.20	$ -	$ -	$ -	$ -	$ -	0	
294	CPU Utilization	2	2						10	0.20	$ -	$ -	$ -	$ -	$ -	2	
283	Navigator Flight Schedule	2	2						20	0.20	$ -	$ -	$ -	$ -	$ -	4	
80	Timely Instrument Contract Financial Reporting	1	2							0.20	$ -	$ -	$ -	$ -	$ -	0	
					Total Green Risk Expected Cost Reserve Impact ($K)						**$ 900**	**$ 105**	**$ 40**	**$ -**	**$ 1,045**		
					Total Green Risk Expected Schedule Reserve Impact (days)												**7**
					Total Expected Cost Reserve Impact ($K)						**$ 3,990**	**$ 3,865**	**$ 5,180**	**$ 5,200**	**$ 18,235**		
					Total Expected Schedule Reserve Impact (days)												**77**

MMS Technical Risks

Open Technical Risks

ID	Risk Title	Risk Consequence	Risk Likelihood
316	AMS Accelerometer Sensor Reliability	4	2
95	Maneuver Execution Accuracy	3	3
138	No Fuel Mass Incl. in Vibe Test for 3 of 4 Obs.	4	1
251	SDP Boom Deployment Testing	4	1
273	Unsteady Propellnat Motion	3	1
64	Magnetic Cleanliness	3	1
90	ADP Boom Deployment Testing	3	1
258	Instrument Aperture Contamination	3	1
270	Manual Setup For TDRS Extended FOV	3	1
255	Mass Margin	3	1
314	Nav Gain Dropout due to Cold Temperatures	3	1
107	Meeting formation maintenance maneuver interval	2	2
307	Latent damage in Star Sensor due to low humidity	2	1
67	Power Margin	2	1

- Technical risks represent risk to mission performance
- No technical risks that have been accepted to date, i.e. no residual risk accepted
- Mitigation efforts are in place with plan to close all technical risks or accept as residual risk prior to launch

MMS Spacecraft Component Procurement Schedule Risk

- MMS Project awarded 16 competitive fixed price contracts for build and delivery of spacecraft components
- Risk of late deliveries by vendors recognized as a risk early on by Project
- On-time delivery performance to date has been mixed…
- Average slip from contracted delivery date has been 2 months

MMS Major Procurement Delivery Slips

Procurement	Contr. Award	Flight #1 Delivery Contract	Flight #1 Current	Flight #1 Slip	Flight #2 Delivery Contract	Flight #2 Current	Flight #2 Slip	Flight #3 Delivery Contract	Flight #3 Current	Flight #3 Slip	Flight #4 Delivery Contract	Flight #4 Current	Flight #4 Slip
Radial Thruster	10/30/09	05/31/11	06/02/11	0 mo	05/31/11	06/14/11	.5 mos	06/30/11	07/15/11	.5 mos	06/30/11	07/29/11	1 mon
Accelerometer	11/17/09	11/17/11	02/03/12	2.5 mos	03/02/12	05/11/12	2.5 mos	06/28/12	08/10/12	1.5 mos	10/18/12	11/23/12	1.25 mos
IS/SC Deck	02/05/10	01/03/11	08/03/11	7 mos	03/02/11	10/04/11	7 mos	04/27/11	11/02/11	6 mos	06/23/11	12/19/11	6 mos
Filter	02/24/10	02/14/11	03/22/11	1.25 mos	02/14/11	03/22/11	1.25 mos	02/14/11	03/22/11	1.25 mos	02/14/11	03/22/11	1.25 mos
Fill & Drain Valve	02/24/10	02/03/11	02/03/11	0 mo	02/03/11	02/03/11	0 mo	02/03/11	05/04/11	3 mos	02/03/11	05/04/11	3 mos
Oscillator	03/03/10	06/03/11	06/16/11	.5 mos	06/03/11	06/16/11	.5 mos	08/03/12	08/29/12	1 mon	08/03/12	08/29/12	1 mon
Digital Sun Sensor	04/08/10	12/08/11	12/08/11	0 mo	03/07/12	03/07/12	0 mo	05/31/12	05/31/12	0 mo	09/24/12	09/24/12	0 mo
Latch Valve	04/14/10	05/24/11	07/15/11	1.5 mos	05/24/11	08/26/11	3 mos	05/24/11	08/26/11	3 mos	05/24/11	08/26/11	3 mos
Axial Thruster	04/16/10	04/15/11	05/27/11	1.5 mos	04/15/11	06/09/11	1.75 mos	04/15/11	06/15/11	2 mos	04/15/11	06/22/11	2.25 mos
Tanks	04/30/10	07/06/11	11/22/11	5.5 mos	09/15/11	01/13/12	4 mos	12/02/11	03/12/12	3.5 mos	02/03/12	05/07/12	3 mos
Star Sensor	05/07/10	09/16/11	11/01/11	1.5 mos	09/16/11	11/01/11	1.5 mos	11/17/11	12/22/11	1 mon	11/17/11	12/22/11	1 mon
Pressure Transducer	05/10/10	05/11/11	07/01/11	1.5 mos	05/11/11	07/01/11	1.5 mos	05/11/11	07/01/11	1.5 mos	05/11/11	07/01/11	1.5 mos
Battery	05/27/10	07/19/13	07/19/13	0 mo	08/02/13	08/02/13	0 mo	09/18/13	09/18/13	0 mo	10/02/13	10/02/13	0 mo
Front End Electr	10/19/10	02/29/12	06/26/12	4 mos	02/29/12	07/11/12	4.5 mos	07/25/12	07/25/12	0 mo	08/08/12	08/08/12	0 mo
Transponder	11/24/10	07/26/11	01/26/12	6 mos	10/24/11	03/21/12	5 mos	01/25/12	06/21/12	5 mos	04/23/12	09/21/12	5 mos
Solar Array	11/30/10	01/07/13	01/07/13	0 mo	03/04/13	03/04/13	0 mo	04/29/13	04/29/13	0 mo	06/24/13	06/24/13	0 mo

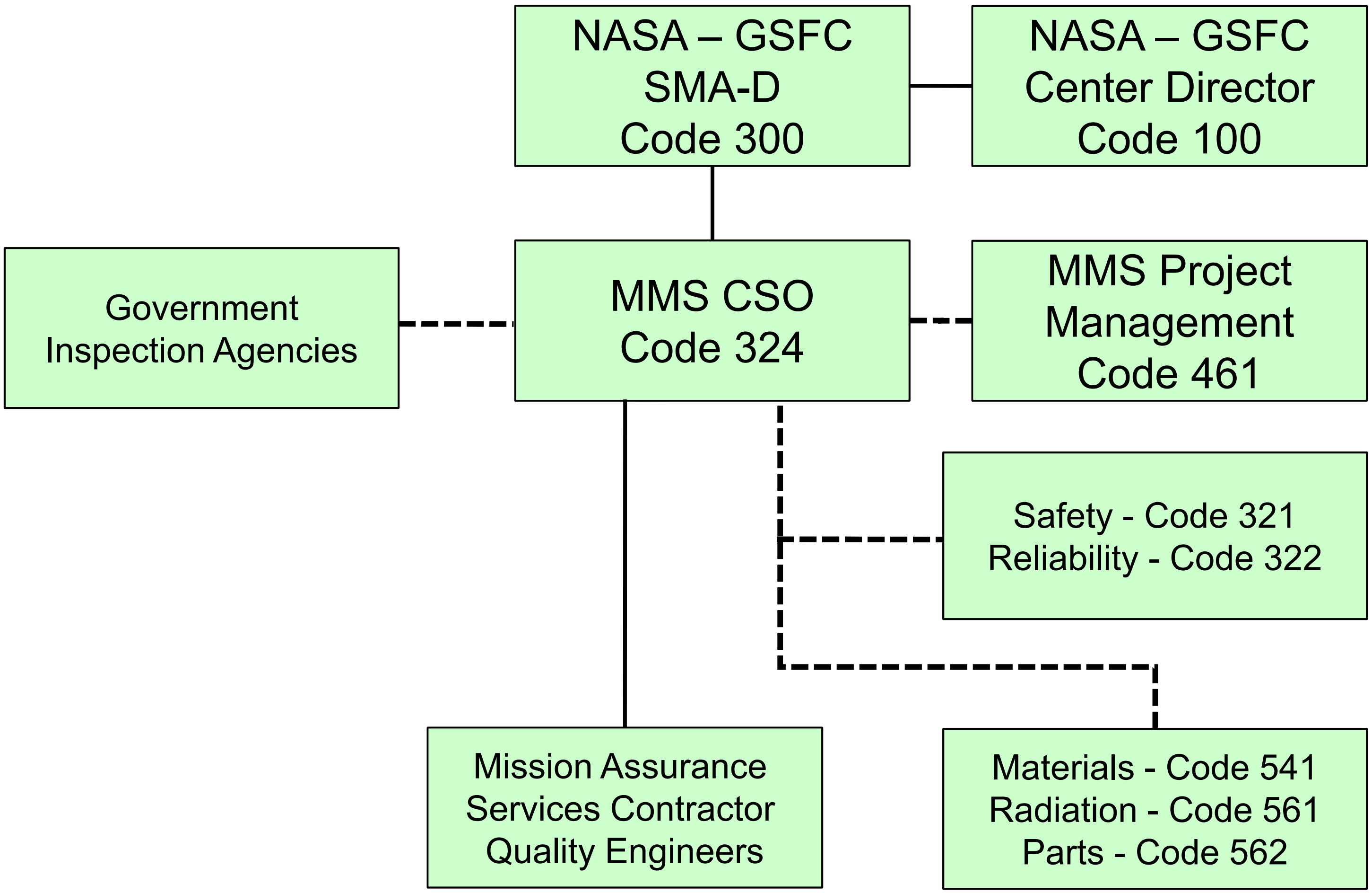
Summary

- Successful Project Management for complex projects requires continuous risk management
- Issues will always occur despite implementation of a risk management process
- Beware of potential quality issues when increasing capacity to meet high quantity needs

Safety & Mission Assurance

John Blackwood
Chief Safety & Mission Assurance Officer
(CSO)

MMS Safety & Mission Assurance Organization Chart



MMS/GSFC S&MA Team

– John Blackwood/324	Chief S&MA Officer (CSO)
– Kamili Jackson/324	Product Assurance Engineer
– George Bertholdt/324	Product Assurance Engineer
– Angela Melito/321	Project Safety Manager/PAE
– Phil Mitchell/ManTech	Project Safety Engineer
– Michelle Perez	Project Safety Engineer
– John Evans/322	Reliability Manager
– Thiago Pires/ManTech	Reliability Engineer
– Ken Hodges	Materials and Processes Engineer
– Mike Xapsos/561	Radiation Lead
– Michael Campola/MEI	Radiation Engineer
– Marcellus Proctor/562	EEE Parts Lead
– Antonio Reyes/MEI	Parts Engineer
– Shyam Parikh/MEI	Parts Engineer
– Luis Munoz/MEI	Parts Engineer
– Heather Dozier/MEI	Parts Materials Coordinator
– Abdullah Dasti/ManTech	Software Quality Engineer
– Mike Swenton/HTSI	Hardware Quality Engineer
– Carl Powell/HTSI	Hardware Quality Engineer
– Ruth Osborne/HTSI	Hardware Quality Engineer
– Keith Corsi/HTSI	Hardware Quality Engineer
– Cindi Lewis/MEI	Hardware Quality Engineer

For the CSO and the SMA team the list is long…

- Development Mission Assurance Requirements for the projects and programs
- Works Project full life-cycle from Concept through Launch
- Ensures implementation of the Mission Assurance Requirements
- Complements the systems review office and systems managers for completion of mission success activities
- Coordinate risks and issues with the Systems Review Manager both before and after major reviews
- Ensures that appropriate oversight of contractors is in place
- CSOs sign off on all project problem reports, failure reports, waivers/deviations and design changes
- Manages assurance program for both in-house and out-of-house Projects
- Problem Report/Problem Failure Report (PR/PFR) System
- Parts Control Board -works closely with Code 562 Parts Engineers
- Implements Government-Industry Data Exchange Program (GIDEP) compliance and dispositions
- Works with Code 541 Materials to determine acceptability of printed wiring boards by coupon evaluation, materials usage, etc
- Ensures parts and materials lists are thoroughly reviewed and acceptable for use
- Coordinates radiation requirements and implementation with Code 561 (Radiation Effects)
- Implements Workmanship Standards such as soldering, cabling, harnessing, conformal coating
- The MA team is co-located with the project office, to provide the most efficient access to the project manager and staff
- MA team must be a good communicator and understand where support is needed and keep the Project in the loop
- MA team members walks a fine line between supporting the Project and Program and remaining an independent entity
- Works with Systems Safety to implement project safety program
- Works with Reliability to implement project reliability program
- Voting member of CCB and risk management board
- Conduct audits/assessments at hardware developers (and provide follow-up)
- Determine mandatory inspection points
- Support in resolution of hardware/software problems
- Member of Source Evaluation/Selection Boards
- Member of Senior Staff Project and Program
- Point of contact for all manpower in Code 300
- Ensure LOD and NCAS task order are written and adhered to
- Attendance and participation at major reviews
- Provide monthly presentations to Code 300 Management
- Provide presentations to Project/Program Management as required
- Presents at the Safety and Mission Success Review (SMSR) to Headquarters
- Launch campaign support and any post launch activities

S&MA – Hardware Quality Assurance

<u>Procurement Support per GPR 5100.1F</u>

- Tailored procurement-specific Quality Requirements from the MMS MAR included in each Statement of Work (SOW)
- Ensure procurements are reviewed by Quality Engineering so that appropriate requirements are flowed down
  - 17 S/C subsystem procurements have varying SMA requirements
- Smaller procurements are handled via task orders on the GSFC Task Order Management System (TOMS)
  - Tasks processed and managed on existing Government contracts
  - Ensure proper flow down of appropriate S&MA requirements

<u>Incoming Inspection per GPR 4520.2E</u>

- Incoming inspections performed through the WOA System
- Anomalies discovered during Incoming Inspection documented and processed in PR/PFR Reporting System (461-SMA-PROC-0102)

S&MA – Hardware Quality Assurance

<u>Mandatory Inspection Points</u>

•Developed & Implemented MMS S&MA Surveillance Plan (461-SMA-PLAN-0120)
•Ensure Mandatory Inspection Points (MIPs) are identified for Circuit Cards, Box Level Assemblies, welds, etc
•Implement the services of a second set of eyes at critical stages as required
- Points where inspection at a later date would be impossible

•Implemented Letters of Delegation (LODs) to DCMA or task orders for Audits, Assessments and Assurance Services (A3) involvement in MMS-subsystems development efforts (Per GSFC 5100.3F – Quality Assurance Letter of Delegation)

<u>Surveillance of Contractors</u>

•MMS SMA philosophy is to have project SMA personnel inspect ETU (and possibly first flight article) before turning responsibility to DCMA or A3

– DCMA/A3 will be used for IS suppliers
– DCMA/A3 to be used for 17 spacecraft subsystem suppliers
– International partners/suppliers a little trickier, some A3 available (Denmark) but not in Japan

S&MA Workmanship Requirements

- NASA Workmanship Standards
  - NASA-STD-8739.1 Polymeric Applications
  - NASA-STD-8739.2 Surface Mount Technology
  - NASA-STD-8739.3 Soldered Electrical Connections
  - NASA-STD-8739.4 Crimping, Cables, Harnesses, and Wiring
- ANSI/ESD S20.20 For the Development of an Electrostatic Discharge Control Program
  - MMS personnel have been certified to GSFC-WM-001 (GSFC Workmanship Manual For ESD)
- Training/Certification shall be IAW Workmanship Standard requirements
- All Workmanship Standards have been flowed down to the appropriate Contractors
- All hardware configurations to be verified prior testing or integration

MMS S&MA Approach with Partners/Suppliers

- Prime contract is with Southwest Research Institute (SwRI)
  - Partnership in place to accomplish the seemingly overwhelming surveillance task associated with the Instrument Suite
    - SwRI, UNH, APL and GSFC are all investigation leads with their own S&MA organizations in place

- Subsystem component providers have either DCMA, A3, or MMS Project S&MA oversight in addition to their own internal S&MA personnel

- As problems arise the approach towards resolution varies
  - Involve GSFC subject matter experts
  - Seek out experiences by other GSFC flight projects using same supplier
  - Insight into vendors processes not always an open book
  - Try to resolve the issues in-house, but keeping the project on sure footing is the underlying theme and more drastic steps are not unheard of
  - Site visits commonplace for project S&MA personnel

- Open communication is the key. We really are there to ensure the project receives a quality product that meets requirements.

Questions?