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

October 18, 2011
Why MMS? - Solar and Space Physics
Decadal Survey Highest Priority

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

<table>
<thead>
<tr>
<th>Rank</th>
<th>Project</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Magnetospheric Multiscale</strong></td>
<td>Four-spacecraft cluster to investigate magnetic reconnection, particle acceleration, and turbulence in magnetospheric boundary regions.</td>
</tr>
<tr>
<td>2</td>
<td>Geospace Network</td>
<td>Two radiation-belt-mapping spacecraft and two ionospheric mapping spacecraft to determine the global response of geospace to solar storms.</td>
</tr>
<tr>
<td>3</td>
<td>Jupiter Polar Mission</td>
<td>Polar-orbiting spacecraft to image the aurora, determine the electromagnetic properties of the Io flux tube, and identify magnetosphere-ionosphere coupling processes.</td>
</tr>
<tr>
<td>4</td>
<td>Multispacecraft Heliospheric Mission</td>
<td>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.</td>
</tr>
<tr>
<td>5</td>
<td>Geospace Electrodynamic Connections</td>
<td>Three to four spacecraft with propulsion for low-altitude excursions to investigate the coupling among the magnetosphere, the ionosphere, and the upper atmosphere.</td>
</tr>
<tr>
<td>6</td>
<td>Suborbital Program</td>
<td>Sounding rockets, balloons, and aircraft to perform targeted studies of solar and space physics phenomena with advanced instrumentation.</td>
</tr>
<tr>
<td>7</td>
<td>Magnetospheric Constellation</td>
<td>Fifty to a hundred nanosatellites to create dynamic images of magnetic fields and charged particles in the near magnetic tail of Earth.</td>
</tr>
</tbody>
</table>
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
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**

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MMS Mission Overview
What is Magnetic Reconnection?

- Magnetic Reconnection is a Fundamental Universal Process
  - 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

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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 \( \leq 30 \) 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.

Scales are in Earth Radii (6378 km)
MMS Observatories Stacked in Atlas-V Rocket Fairing

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MMS Observatory - Deployed

Axial Double Probe (ADP) = 14.75 meter [48.4']
(12.5 meter coilable boom + 2.25 meter receiving element)
provider: LASP

Single Plane Double Probe (SDP) = 60 meter [196.9']
provider: UNH

Magnetometer boom = 5 meter [16.4']
provider: GSFC
Deployed MMS Observatory – to scale
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

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MMS Mission Overview
C. Tooley/NASA-GSFC-461 19
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

Subproject and partner data/constraints, hazard analysis, FMEA, FTA, etc.

Risk data: test data, expert opinion, hazard analysis, FMEA, FTA, lessons learned, technical analysis

Statement of risk

Identify risk issues and concerns

Risk classification
Likelihood
Consequence
Timeframe
Risk prioritization

Evaluate (impact/severity, probability, timeframe), classify, and prioritize risks

Research
Watch (tracking requirements)
Acceptance Rationale
Mitigation Plans

Decide what, if anything, should be done about risks

Close or Accept Risks
Invoke contingency plans
Continue to track

Monitor risk metrics and verify/validate mitigation actions

Make Risk Decisions

Program/project data (metrics information)

Resources
Repain Mitigation

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

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NAR - 25
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

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

### Consequence Categories

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

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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

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

<table>
<thead>
<tr>
<th>Risk ID</th>
<th>Approach</th>
<th>Risk Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>Launch Opportunities</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>Environmental Test Facility Conflict</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>FPI Cost Increase/Schedule</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>I&amp;T Schedule</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>Manufacturing Delays</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>Sparing Philosophy</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>I&amp;T Staffing</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>Maneuver Execution Accuracy</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>Multiple Build Rework</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>EDI Schedule/Gun Focus</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>Phase E Cost</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>Institution Facility/Cost</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>Clean Room Completion Schedule</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>HPCA</td>
</tr>
<tr>
<td>15</td>
<td>M</td>
<td>AMS Accelerometer Sensor Reliability</td>
</tr>
</tbody>
</table>

Criticality: High, Med, Low

Approaches: M - Mitigate, W - Watch, A - Accept, R - Research

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NASA Supply Chain Quality Assurance Conference - MMS Risk Management

NAR - 33
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)

<table>
<thead>
<tr>
<th>Risk ID</th>
<th>Risk Title</th>
<th>Risk Consequence</th>
<th>Risk Likelihood</th>
<th>FY12 Impact</th>
<th>FY13 Impact</th>
<th>FY14 Impact</th>
<th>FY15 + Impact</th>
<th>Total Impact</th>
<th>Probability</th>
<th>FY12 Impact</th>
<th>FY13 Impact</th>
<th>FY14 Impact</th>
<th>FY15 + Impact</th>
<th>Total Schedule Impact (days)</th>
<th>Critical Path Impact (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>274</td>
<td>Launch Opportunities</td>
<td>4</td>
<td>3</td>
<td>0.60 $</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>12</td>
<td>-</td>
<td>12</td>
</tr>
<tr>
<td>301</td>
<td>Environmental Test Facility Conflict</td>
<td>6</td>
<td>3</td>
<td>20</td>
<td>0.60 $</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>12 $</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>291</td>
<td>PPI Cost Increase / Schedule</td>
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MMS Technical Risks

Open Technical Risks

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<td>Power Margin</td>
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</table>

- 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

Oct 18, 2011

NASA Supply Chain Quality Assurance Conference - MMS Risk Management
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

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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)

Oct 18, 2011

NASA Supply Chain Quality Assurance Conference - MMS Risk Management
MMS Safety & Mission Assurance Organization Chart

NASA – GSFC
SMA-D
Code 300

NASA – GSFC
Center Director
Code 100

MMS CSO
Code 324

MMS Project Management
Code 461

Safety - Code 321
Reliability - Code 322

Mission Assurance Services Contractor
Quality Engineers

Materials - Code 541
Radiation - Code 561
Parts - Code 562

Government Inspection Agencies
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

Procurement Support per GPR 5100.1F

• 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

Incoming Inspection per GPR 4520.2E

• 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

Mandatory Inspection Points

• 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)

Surveillance of Contractors

• 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.