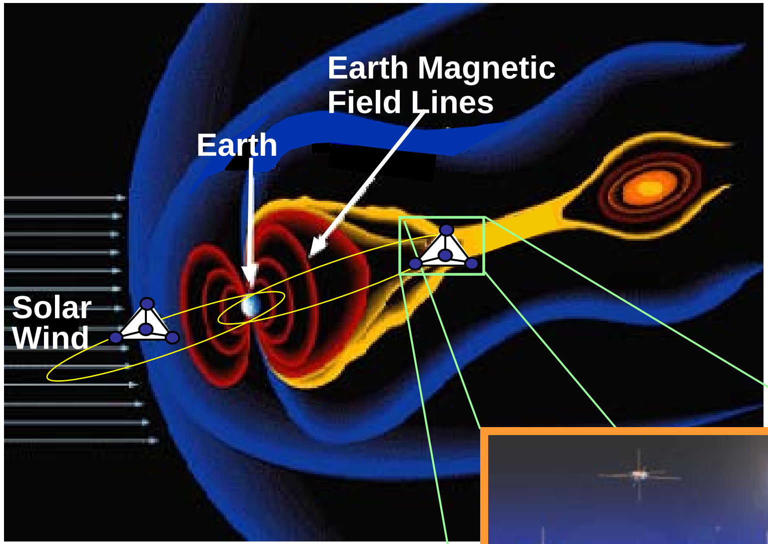
Instrument Suite Development for the Magnetospheric Multiscale Mission

Supply Chain Quality Assurance Conference
October 18th – 20th 2011

MMS
managing risk on a global scale

Ronald K. Black, Program Director
Thomas C. Trbovich, Director
Joerg Gerhardus, Manager

MMS Overview



Mission Team

NASA SMD

Southwest Research Institute

- **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

Mission Status

Currently in Phase C/D

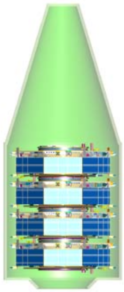
Launch in 2014

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

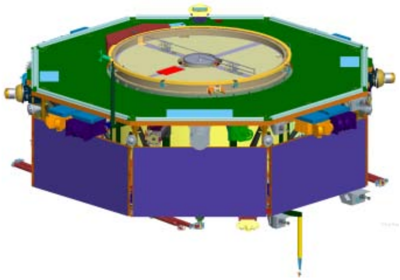
- Phase 1 day side of magnetic field 1.2 R_E by 12 R_E
- Phase 2 night side of magnetic field 1.2 R_E by 25 R_E

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

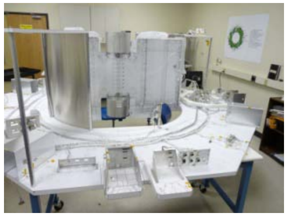
Magnetic and electrostatic cleanliness

Launch Vehicle

4 satellites launched together in one Atlas V

MMS… A Huge Endeavor

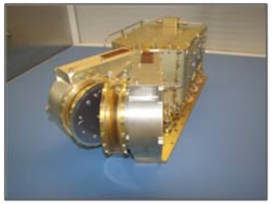
- Four Spacecraft
- Five Investigations/Instruments
- Eleven sensors, three electronics boxes
- 33 End-Item Instrument Suite components per spacecraft – 132 total end-item components
- 10 U.S. hardware institutions, 7 foreign institutions

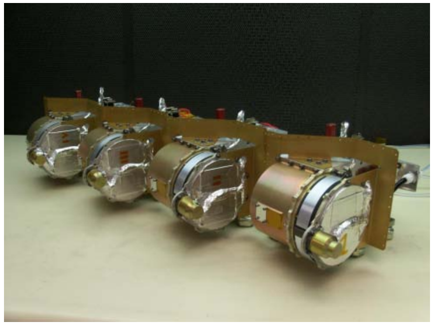

Instrument EM Harness


CIDP ETU

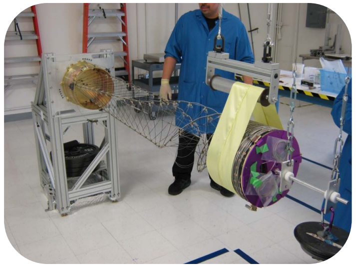

FIELDS CEB FM1

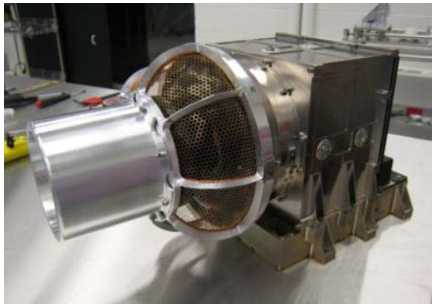

FPI DIS ETU

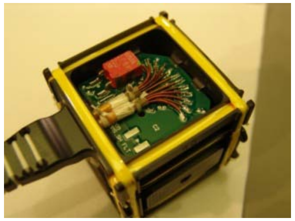

FPI DES ETU

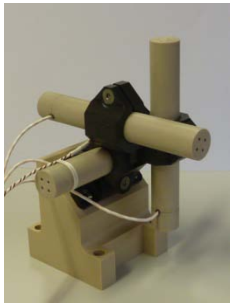

EIS FM


ASPOC ETU

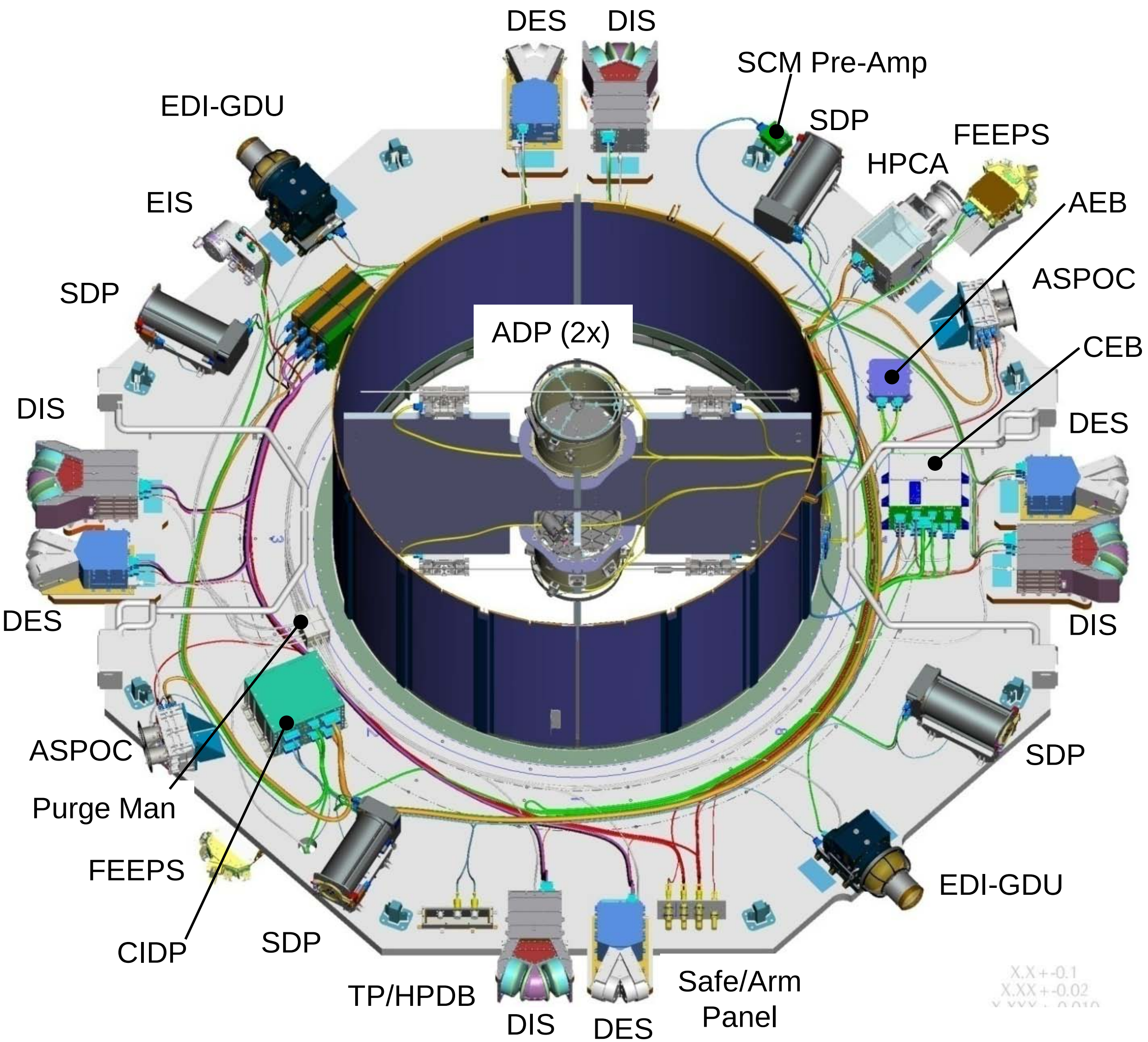

FIELDS ADP FM1


FIELDS EDI ETU


FIELDS DFG Sensor FM1


FIELDS SCM QM

MMS Instrument Suite Components



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 - Electron Drift Instrument
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

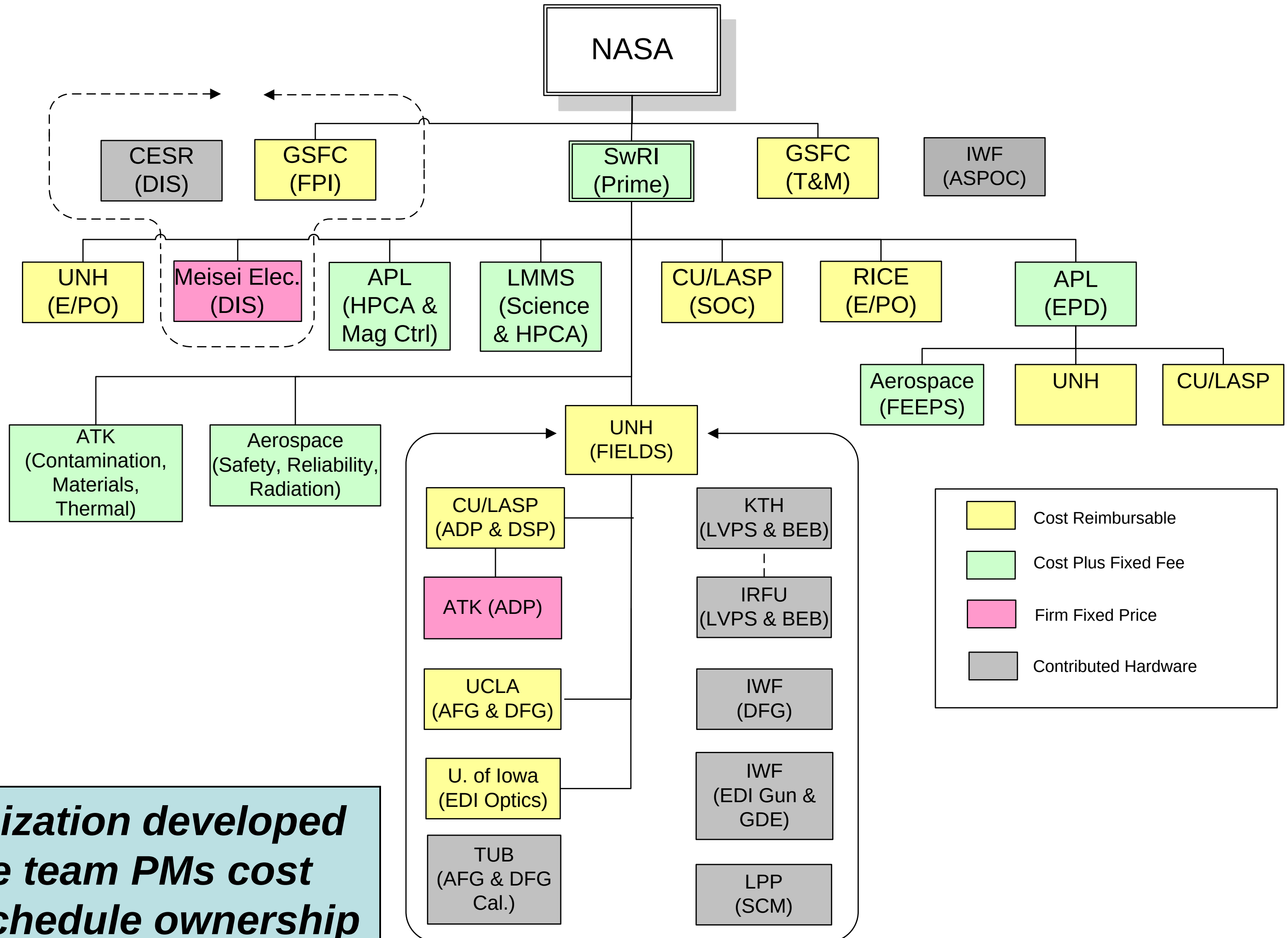
Project Planning – 1 of 2

- **Team Organization**
  - Teams usually organized around specialties
    - Critical for teams to have ownership of cost and schedule
- **Clear Scope of Project**
  - Statement of Work (SOW)
  - Create Work Breakdown Structure (WBS) and baseline
  - Mission Assurance Requirements
- **Establish Firm Expectations**
  - Milestones
  - Contracting and costing assumptions
  - ITAR
  - Meetings and Reviews
  - Reporting (technical, schedule, cost, EV)
  - System engineering activities (requirements, interfaces, analyses, models, etc.)
  - Hardware and software deliverable units
  - Environment and testing requirements
  - Post delivery support
  - Science Operations

Project Planning – 2 of 2

- **Achieving common ground and plan ahead**
  - Agree to a common language
  - Tailor Mission-level Mission Assurance Requirements document before flowing down to investigations and partner organizations
  - Account for global differences
    - ESA or JAXA specifications do not necessarily match NASA requirements
  - Generate organization specific Product Assurance Implementation Plans
    - Identify potential gaps
  - Utilize Lessons Learned from past NASA projects
  - Prepare to provide Instrument Suite level support to teams
    - Hardware inspections
    - EEE parts and materials procurement (dual sourcing of critical printed circuit boards)
    - Reliability analyses support
    - Radiation analyses and testing support
    - Safety planning & implementation

SMART Instrument Suite Organization



Organization developed to give team PMs cost and schedule ownership

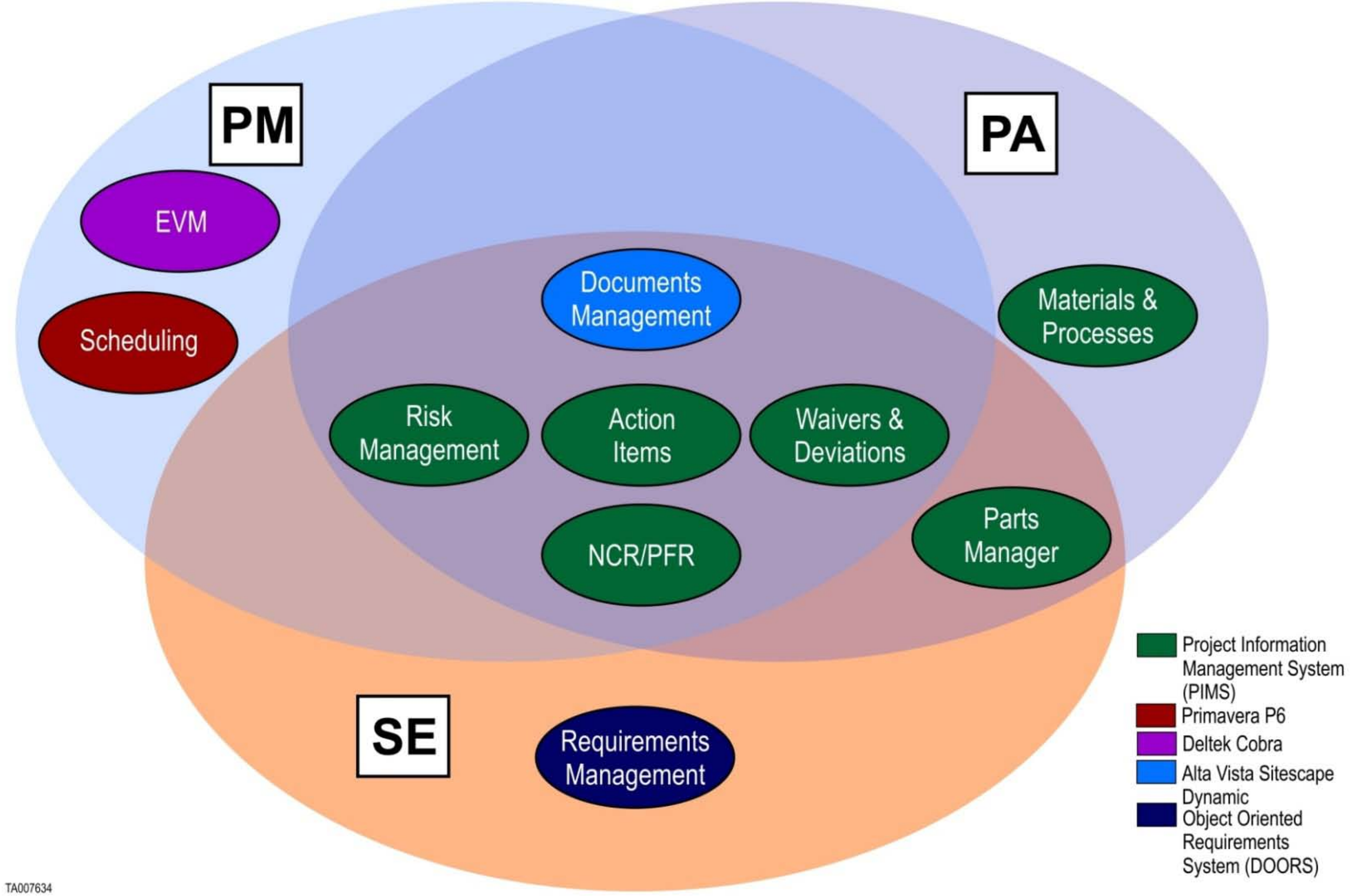
MMS Instrument Suite WBS

SMART-MMS WBS

- **1.0 PROGRAM MANAGEMENT**
  - TECHNICAL MGMT
  - PLANNING, COST & SCHEDULING
  - PAYLOAD REVIEWS
  - SUBCONTRACT ADMINISTRATION
  - DOCUMENT & DRAWING CONTROL
  - CONFIGURATION MGMT
  - CONTRACT DATA REQUIREMENTS
- **2.0 SCIENCE**
  - SCIENCE OVERSIGHT
  - NON-HDWR CO-I SCIENCE SUPPORT
  - REVIEW SUPPORT
  - CALIBRATION
  - MODELING & SIMULATION
  - MISSION DESIGN & ANALYSIS
  - CONTRACT DATA REQUIREMENTS
  - MO&DA
- **3.0 SYSTEMS ENGINEERING**
  - SUSTAINING SE SUPPORT
  - IS REQUIREMENTS & ICD'S
  - TRADE / SPECIAL STUDIES
  - VERIFICATION
  - CONTRACT DATA REQUIREMENTS
  - MISSION OPERATIONS
- **4.0 MISSION ASSURANCE & SAFETY**
  - PERFORMANCE ASSURANCE
  - QUALITY ASSURANCE
  - SAFETY ENGINEERING
  - RELIABILITY ENGINEERING
  - EEE PARTS ENGINEERING
  - CONTAMINATION CONTROL
  - CONTRACT DATA REQUIREMENTS
- **5.0 INSTRUMENT DEVELOPMENT & DATA ANALYSIS**
  - **5.1 FAST PLASMA INVESTIGATION (GSFC)**
    - INSTRUMENT MANAGEMENT
    - INSTRUMENT SCIENCE
    - INSTRUMENT SYSTEMS ENG.
    - PRODUCT ASSURANCE
    - ION SENSORS
    - ELECTRON SENSORS
    - IDPU
    - FPI ASSEMBLY I&T
    - FPI GSE
    - FPI POST DELIVERY SUPPORT
    - FPI MO&DA
  - **5.2 FIELDS INVESTIGATION (UNH)**
    - INSTRUMENT MANAGEMENT
    - INSTRUMENT SCIENCE
    - INSTRUMENT SYSTEMS ENG.
    - PRODUCT ASSURANCE
    - CENTRAL ELECTRONICS BOX
    - ELECTRON DRIFT INSTRUMENT
    - DIGITAL SIGNAL PROCESSOR
    - ANALOG FLUX GATE MAG
    - DIGITAL FLUX GATE MAG
    - SEARCH COIL MAGMETOMETER
    - SPIN PLANE DOUBLE PROBE
    - AXIAL DOUBLE PROBE
    - MAG BOOMS
    - FIELDS ASSEMBLY INTEGRATION & TEST
    - FIELDS GSE
    - FIELDS POST DELIVERY SUPPORT
    - FIELDS MO&DA
  - **5.3 ENERGETIC PARTICLES DETECTOR INVESTIGATION (APL)**
    - INSTRUMENT MANAGEMENT
    - INSTRUMENT SCIENCE
    - INSTRUMENT SYSTEMS ENG.
    - PRODUCT ASSURANCE
    - EIS SENSOR
    - FEEPS
    - EPD POST DELIVERY SUPPORT
    - EPD MO&DA
  - **5.4 ION COMPOSITION INVESTIGATION (SWRI)**
    - INSTRUMENT MANAGEMENT
    - INSTRUMENT SCIENCE
    - INSTRUMENT SYSTEMS ENG.
    - PRODUCT ASSURANCE
    - NRE / BREADBOARDS
    - EM / PRE-PRODUCTION
    - FM INSTRUMENTS
    - INSTRUMENT GSE
    - POST DELIVERY SUPPORT
    - MO&DA
  - **5.5 ACTIVE SPACECRAFT POTENTIAL CONTROL DEVISE (IWF)**
    - INSTRUMENT MANAGEMENT
    - INSTRUMENT SCIENCE
    - INSTRUMENT SYSTEMS ENG.
    - PRODUCT ASSURANCE
    - NRE / BREADBOARDS
    - EM / PRE-PRODUCTION
    - FM INSTRUMENTS
    - ASPOC GSE
    - ASPOC POST DELIVERY SUPPORT
    - ASPOC MO&DA
  - **5.6 CENTRAL INSTRUMENT DATA PROCESSOR (SWRI)**
    - CIDP MANAGEMENT
    - CIDP SYSTEMS ENGINEERING
    - PRODUCT ASSURANCE
    - NRE / BREADBOARDS
    - EM / PRE-PRODUCTION
    - FM INSTRUMENTS
    - CIDP GSE
    - CIDP POST DELIVERY SUPPORT
    - CIDP MISSION OPS SUPPORT
- **6.0 FLIGHT SOFTWARE**
  - SOFTWARE MANAGEMENT
  - SOFTWARE SYSTEMS ENGINEERING
  - SOFTWARE QA
  - REQUIREMENTS DEVELOPMENT
  - CODE & UNIT TEST
  - SOFTWARE I&T
  - SUSTAINING ENGINEERING
  - SOFTWARE TOOLS /COTS
- **7.0 IS INTEGRATION & TEST**
  - IS I&T MANAGEMENT
  - IS GSE
  - IS HARNESSING
  - IS PURGE SYSTEM
  - IS SAFE/ARM PANEL
  - IS THERMAL ELEMENTS
  - IS INTEGRATION & TEST
- **8.0 POST-DELIVERY SUPPORT**
  - MANAGEMENT
  - FIELD ENGINEERING SUPPORT
- **9.0 SCIENCE OPS & DATA ANALYSIS**
  - SOC UNIQUE HARDWARE
  - SOC UNIQUE SOFTWARE
  - SOC MANAGEMENT
  - SOC SYSTEMS ENGINEERING
  - SOC CONTROLLER TRAINING
  - SOC I&T SUPPORT
  - SOC FLIGHT OPERATIONS CONTROL
  - SCIENCE DATA PRODUCTS
- **10.0 EDUCATION / PUBLIC OUTREACH**
- **11.0 MISSION RESERVES**

An effective WBS establishes the baseline for all Project reporting

Tools to Manage…



Maximum efficiency is gained in effective use of database tools to manage project information

Tracking Progress…

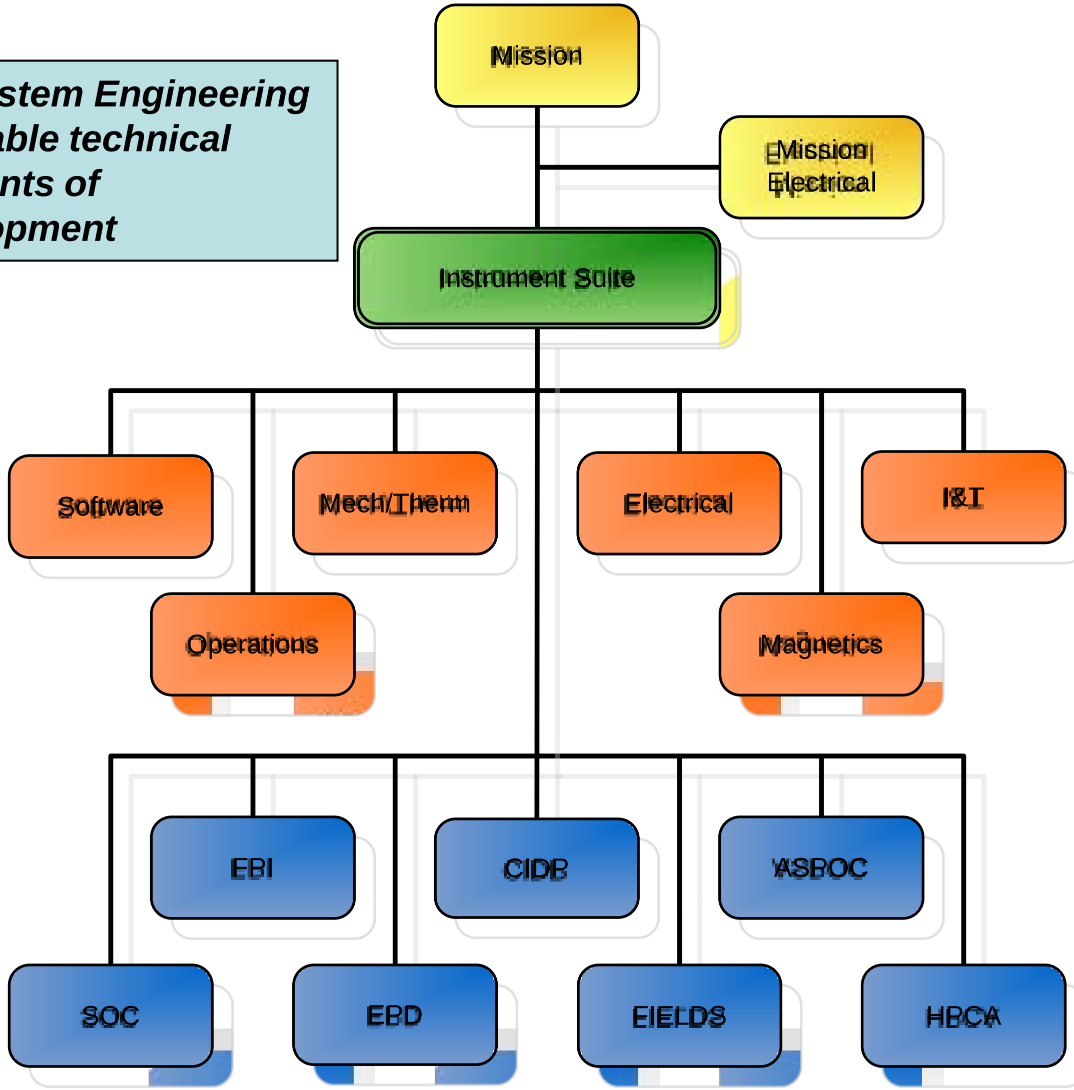
Management Process	Tool	Metrics/Reports
Scheduling	Primavera Project Enterprise P3e	Slack summary, monthly trends, milestone planned/accomplished.
Cost	Primavera Project P6/Deltek Cobra	BCWP (earned value), ACWP, cost variance, ETC, EAC, SPI, CPI, NASA 533M and 533Q cost reports.
Risk	SwRI Risk Management System (RMS)	Risk planned vs. actual retirement rate, risk status reports, risk trends.
Reviews	SwRI Action Item Management System (AIMS)	Action item planned vs. actual closure rate and concurrence status.
Reserves	Excel	Mass/power reserve usage trends.
Requirements/ Verification	DOORS	Planned vs. actual burn down of verification closure.

Check and Act…

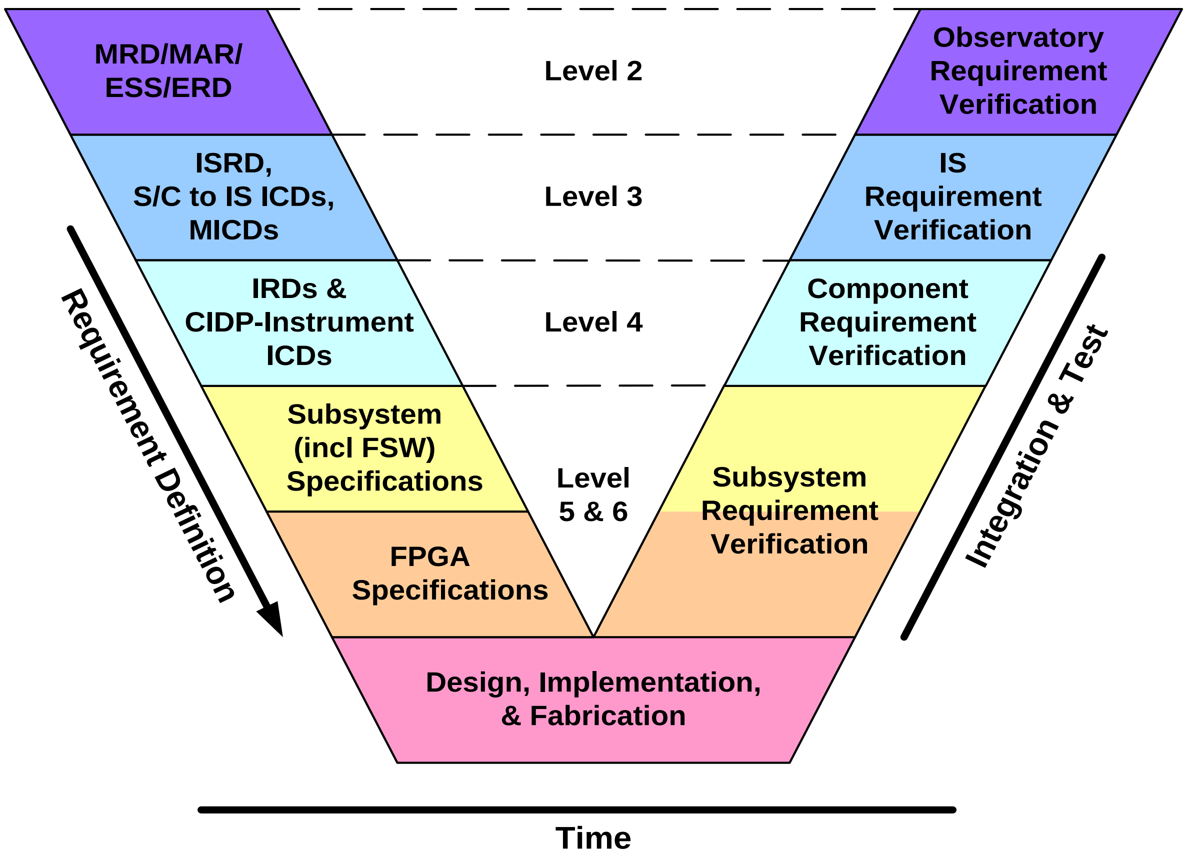
Metric	Reaction
Negative schedule trends	Work with team leadership to determine root cause. Where needed, loan resources (e.g. specialist, facility, parts, special process) or move work to another team member.
Negative earned value (cost variance)	Work with team leadership to determine root cause. Review/revise requirements and/or staffing. Descope work or move work to another team member.
Risk retirement rate too slow	Work with team leadership to determine root cause. Update risk retirement dates. Plan new mitigations.
RFA responses too slow	Bring closure rate to the attention of the actionee, offer help. Follow up on weekly basis until RFAs closed.
Resource usage exceeds plan	Hold peer review on problem instrument, consider alternative design. Release reserves. Consider descope.
Verification closure too slow	Review verification ownership, loan resources, replan closure rate.

Systems Engineering Organization

Instrument Suite System Engineering team provides valuable technical support to all elements of investigation development



Systems Engineering – Managing Requirements

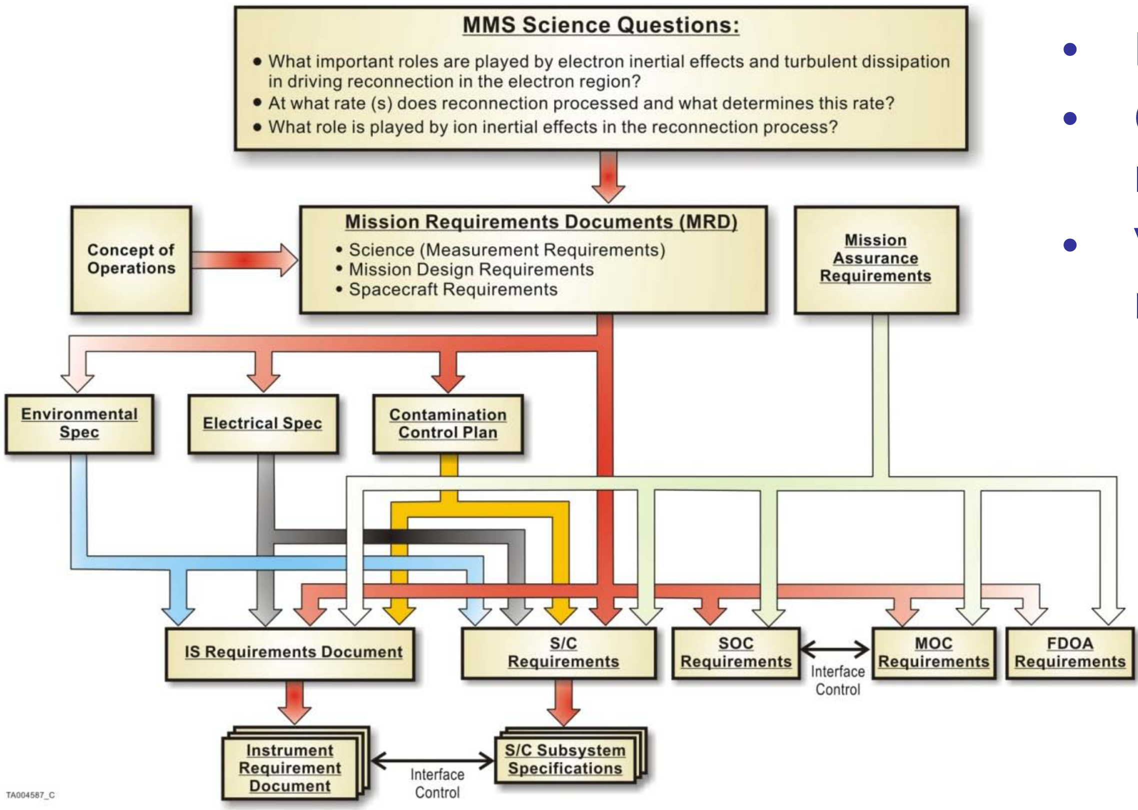


Requirements management begins with concise and baseline set of Program-Level Requirements (Level 1)

System Engineering Process

PDR | CDR | PER | PSR

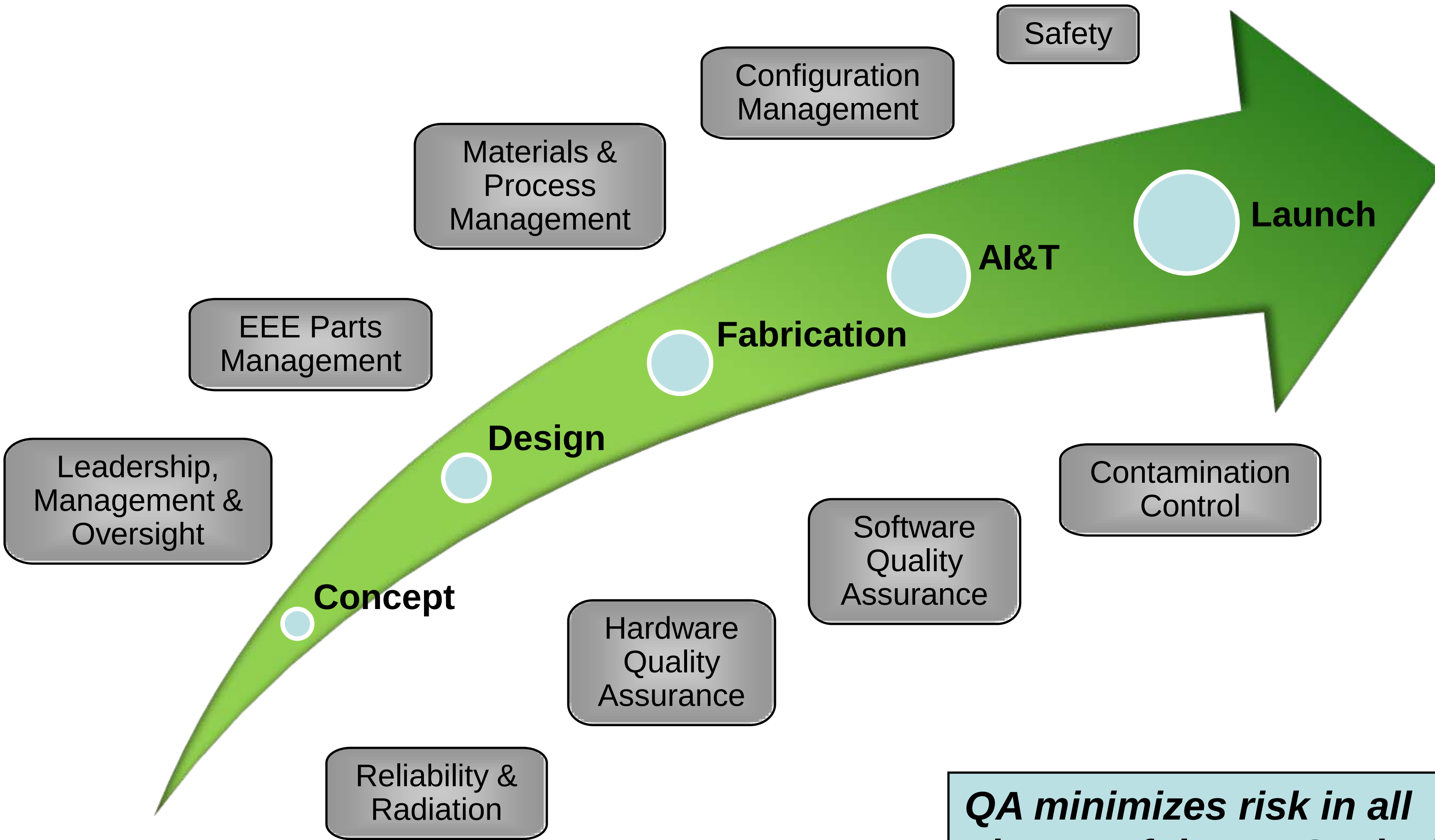
Requirement Management Planning/Flowdown → **Design Analysis/Inspection** → **Subsystem Testing** → **CPT & Environmental Testing**



- Documentation Review
- Check that system works as needed
- Verify that design implementation meets requirements

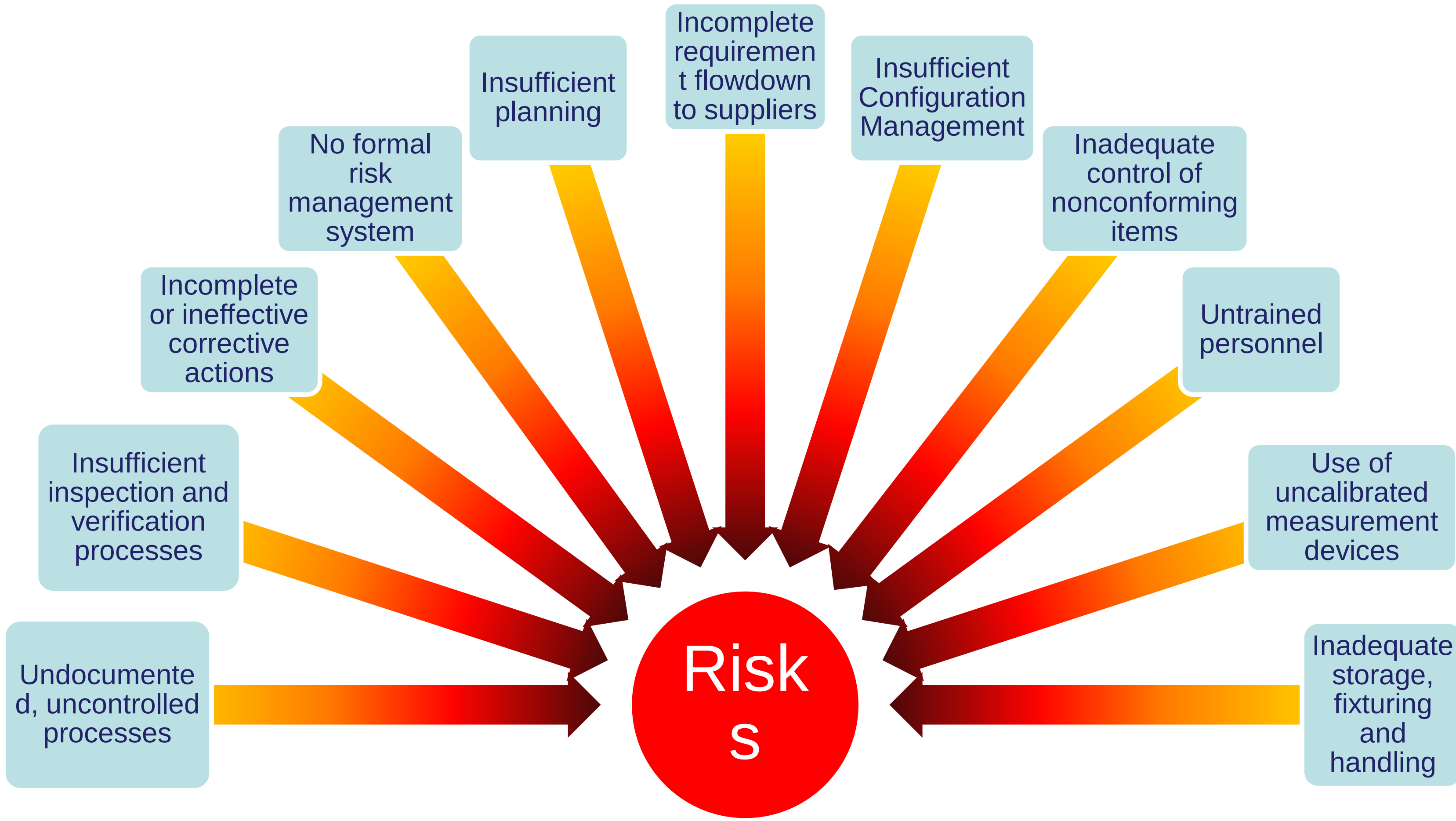
Planning a well organized requirements process minimizes downstream risks

MMS Quality Assurance Pillars



QA minimizes risk in all phases of the MMS mission

Managing Risk During Process Control



Risk Management and ISO 9001-based Quality Management Systems are a perfect match to see warning signs

Keys to Managing Risks

- Programmatic and technical planning in Phase A/B critical to mission success
- Design to requirements and not goals
  - *“Better is the enemy of good enough.”*
- Maintain good team communications
- Develop good set of tools to manage process and to facilitate reporting
- Maintain strong synergy between PM, SE and PA elements