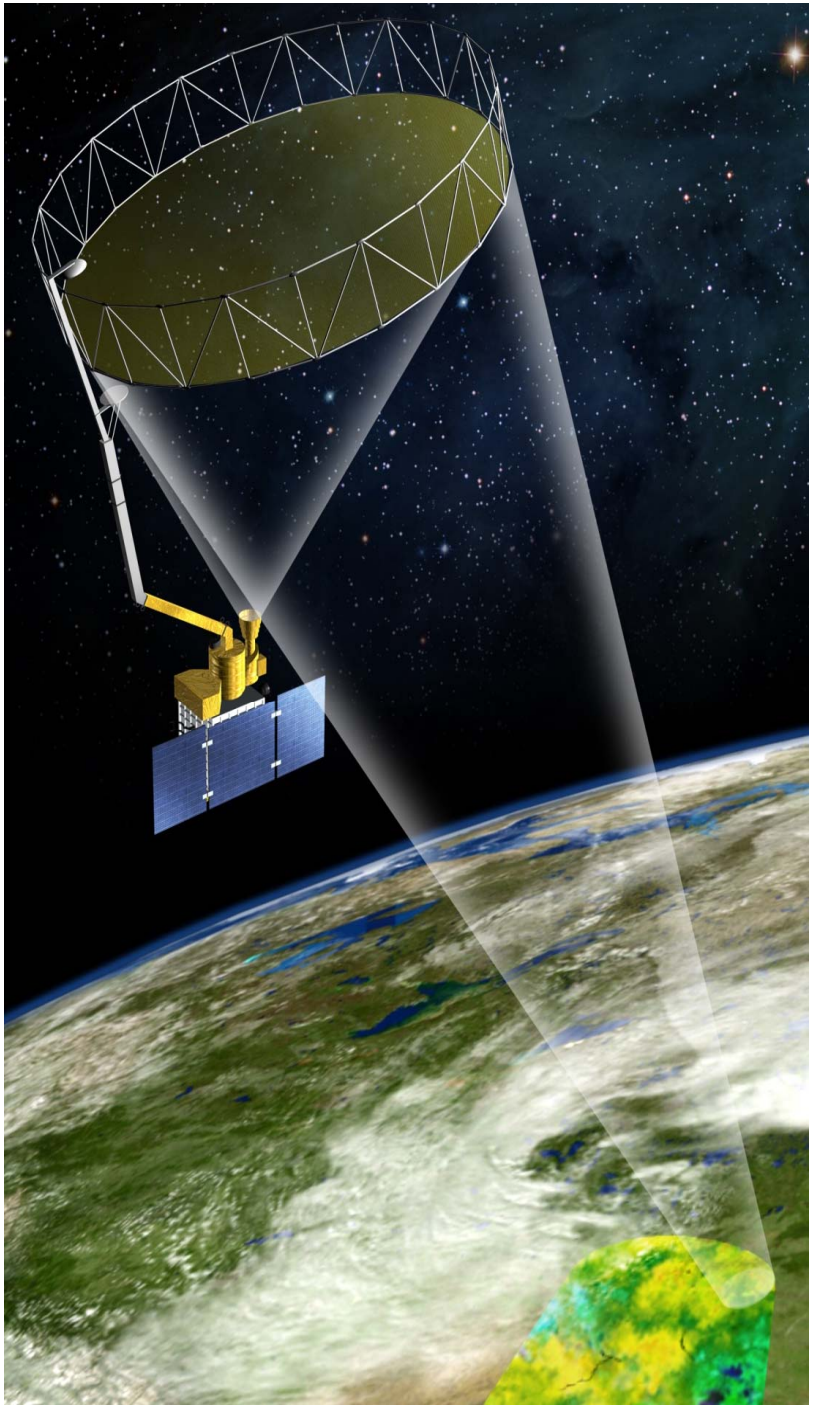


Assessing the Ground Data System Automation That Enables Lights- Out Operation of SMAP

Ground System Architectures Workshop
March 1-3, 2016

Antonio Sanders
Jet Propulsion Laboratory, California Institute of Technology
Pasadena, CA

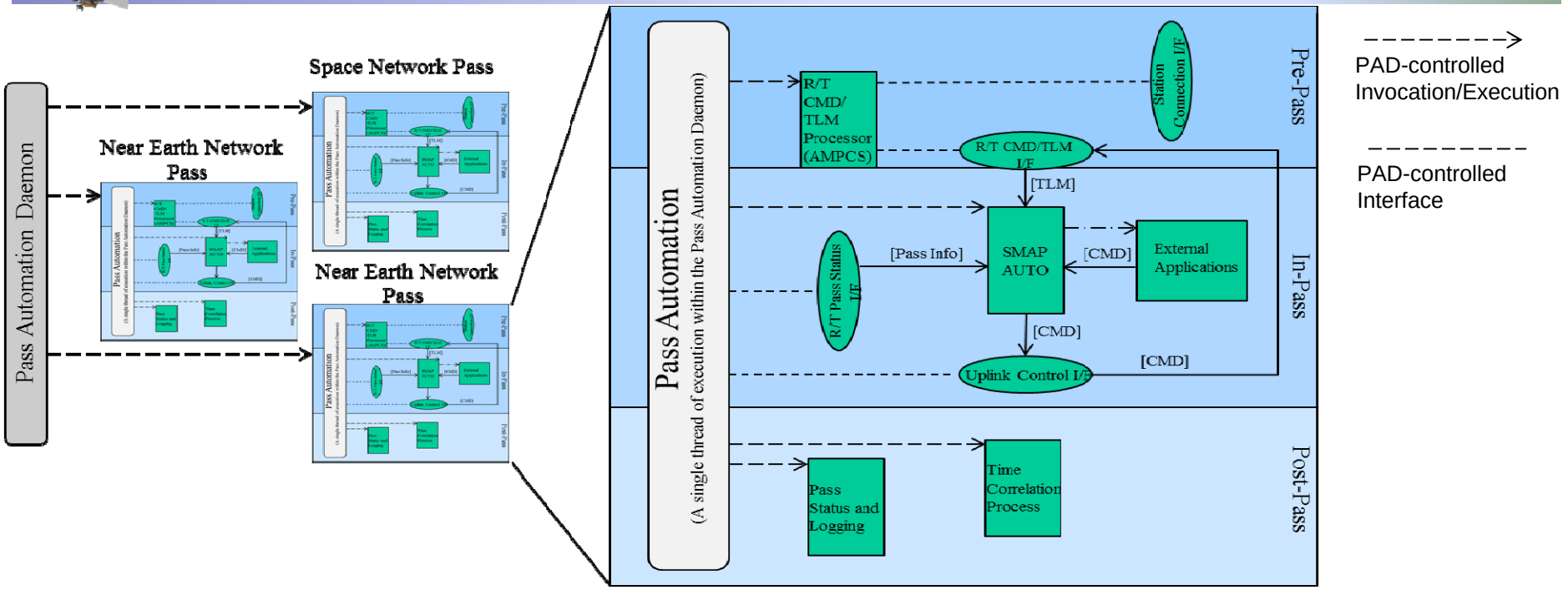
Chris Swan
Jet Propulsion Laboratory, California Institute of Technology
Pasadena, CA

http://smap.jpl.nasa.gov

Introduction

- Soil Moisture Active/Passive (SMAP) is a first tier mission in NASA's Earth Science Decadal Survey
- SMAP is providing a global mapping of soil moisture and its freeze/thaw states
- SMAP is the first JPL flight project to achieve lights-out operations through the use of ground based automation
- Automation achieved by key automation software
  - Pass Automation Daemon (PAD)
  - File Notification Service (FNS)
  - SMAP AUTO
  - AMPCS
  - Data Management Tool (DMT)
  - Alarm Notification Filter (ANF)
  - Telemetry Query and Reporting (TQR)
  - Traceable Automation Remote Display Interruptible Scheduler (TARDIS)
- This presentation will focus on PAD, FNS, and SMAP AUTO

Pass Automation Daemon (PAD)

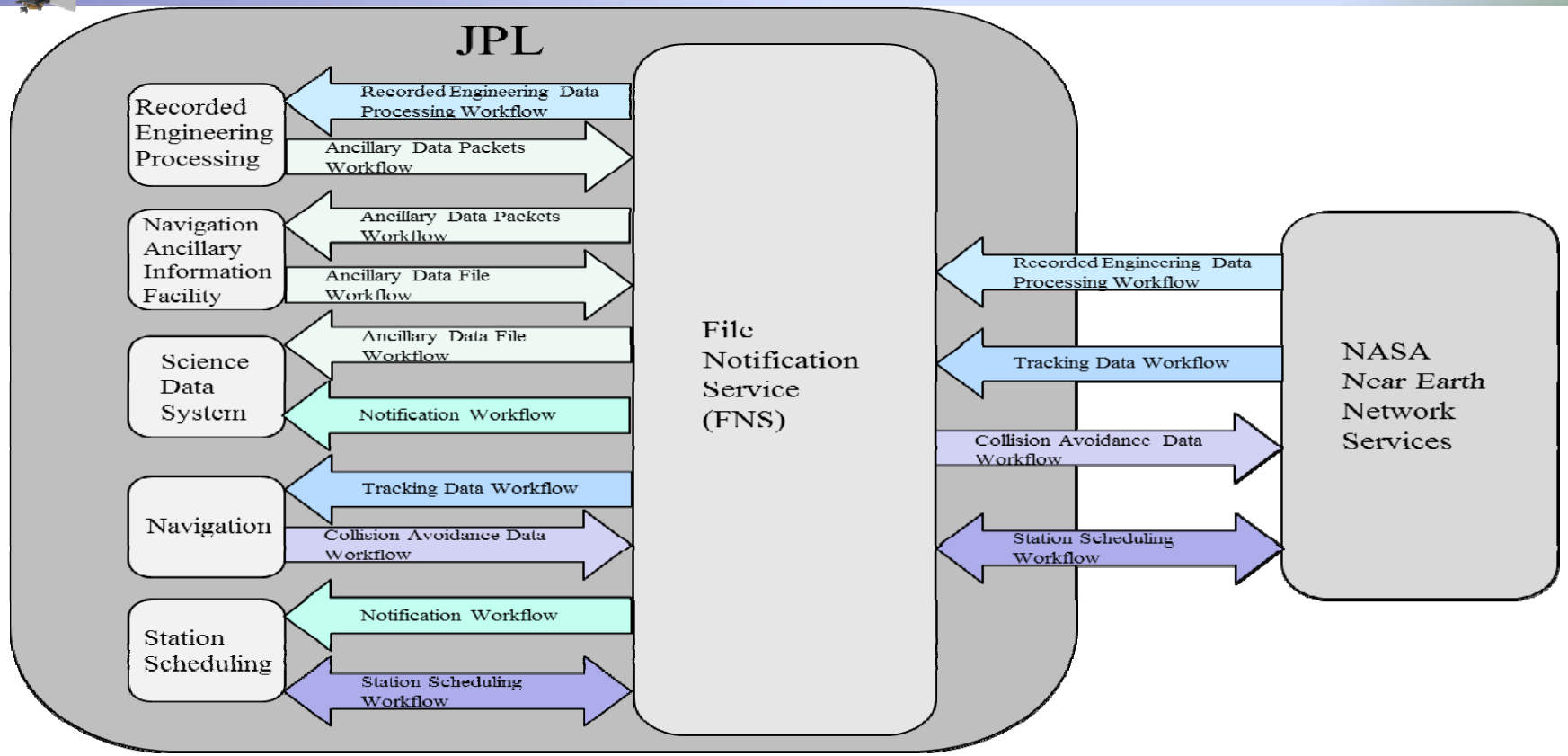


- PAD is the automation engine that drives the ground based pass automation used by SMAP
- PAD performs multiple, simultaneous, overlapping tracking passes across NASA Near Earth Network and NASA Space Network ground stations
- PAD performs pass automation through the integration and orchestration of the capabilities of existing NASA multi-mission and project developed ground system components

Integration:
NASA AMMOS multi-mission command and telemetry processing, project level uplink automation, project level time correlation, PAD internal pass processing, etc.

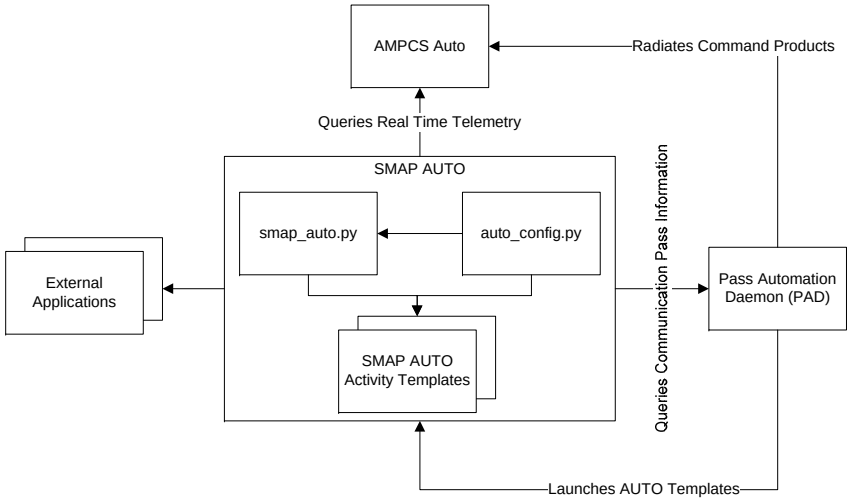
Orchestration:
All activities required for pass automation such as command and telemetry connection/disconnection to ground stations, real-time uplink/downlink processing, and post-pass activities

File Notification Service (FNS)



- FNS is the automation engine that provides the file-based event-driven workflow automation used by SMAP
- FNS defines a set of atomic operations that can be dynamically composed to perform high-level workflow activities that satisfy project operational tasks
  - Sample workflow activity:
    - Retrieve a recorded engineering file from the ground station, process the recorded engineering file, and then invoke application ‘y’ to analyze the data
- FNS workflows are used to perform operational tasks across project teams

AUTO



AUTO Templates	
Data Management (engineering and science)	Activity Master (regular spacecraft maintenance)
Command Loss Update	Bulk File Upload
Update on board Ephemeris	Bad Block Masking
Instrument Commanding Updates (based on current trajectory)	

- AUTO is a interface provided by the NASA AMMOS Mission Data Processing and Control System (AMPCS) to query real time telemetry and radiate command products
- SMAP AUTO is a project specific library and scripts that utilize that interface to perform closed loop commanding of the SMAP spacecraft.
- This is orchestrated by PAD which launches SMAP AUTO templates during selected communication passes.
- SMAP AUTO is divided into a function library, a configuration file, and a selection of activity templates which implement a defined set of commanding.
  - The configuration file allows SMAP AUTO to be operationally adjusted and ensures that the library and templates can be run in a test environment without modification.
- Each template
  - Checks health of the spacecraft
  - Waits for commandability
  - Builds required products
    - This is often a multi-step process that combines ground developed products and inputs with current spacecraft telemetry.
  - Uplinks and verifies receipt
- If SMAP AUTO encounters an off nominal scenario (at any point) it aborts and notifies the mission operations team (email/SMS).
- Each SMAP AUTO template is designed to be self contained within a typical SMAP communication pass (~8 minutes)

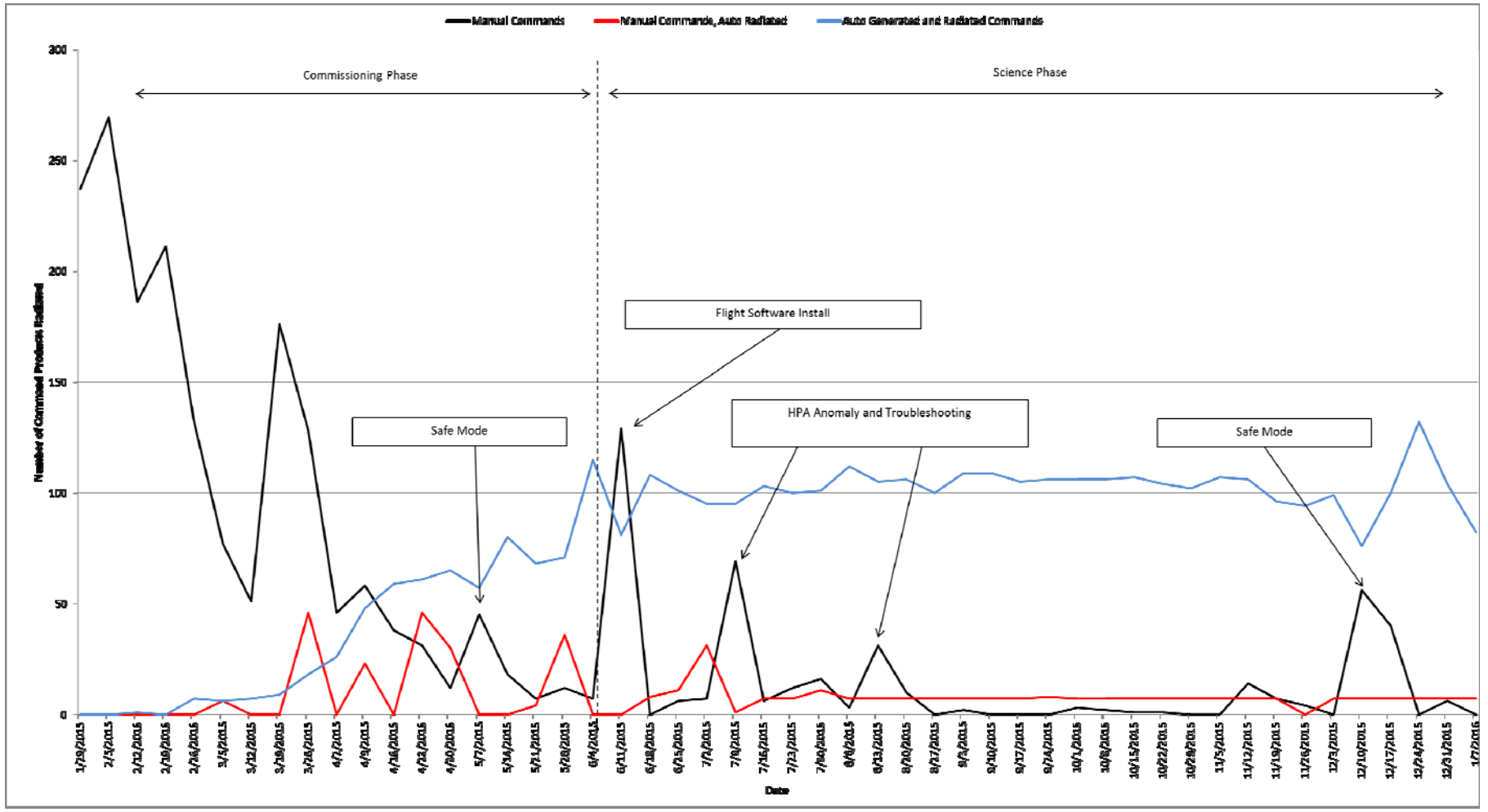
Test Program

- PAD and FNS
  - Early development of key capabilities allowed extensive soak time in testbeds
  - Exercised extensively during System Level tests and ground station testing
  - Immediate Introduction to Flight
    - 24/7 staffed backup provided for first week of operations
- SMAP AUTO
  - Approach based on test automation software libraries used extensively on SMAP and MSL. Kept the design simple and safe
  - Involved cross disciplinary team for requirements development and detailed code review
  - Extensive Ground Testing performed:
    - Performed using SMAP Hardware Test Bed
    - Tested in Nominal and Off-Nominal Scenarios, every path possible
    - Executed in multiple System Level tests
  - Phased Introduction to Flight
    - Simple functions (e.g. Command Loss Timer) introduced first
    - More complex functions “Shadowed” operations team for several weeks

Flight Performance

- PAD
  - Successful Automated Passes (1/31/2015 – 1/20/2016): 6,454
  - Missed/Failed Tracking Pass Orchestrations: 15
    - Does not include ground station or SMAP AUTO anomalies
  - Success Percentage: 99.8%
  - Provides an estimated workforce savings of 3-4 FTE
- FNS
  - Successfully Performed Workflow Activities (1/31/2015 – 1/20/2016): 515,826+
  - Failed Workflow Activities: 48
  - Success Percentage: 99.99%
  - Provides an estimated workforce savings of 3-6 FTE
- SMAP AUTO
  - Currently performs 90% of all SMAP commanding
  - Decreases data latency, improves on-orbit pointing accuracy,
  - Robust to off-nominal scenarios
    - Encountered multiple in-flight anomalies, aborted, notified mission operations team.
  - Provides an estimated workforce savings of 8-10 FTE

Flight Performance (SMAP AUTO)



Application for Multi-Mission

- The PAD and FNS capabilities contain no project specific code and can be applied to other missions through configuration file adaptation
  - However, PAD is tightly coupled to the NASA AMMOS Command and Telemetry system (AMPCS)
    - Missions that use NASA AMMOS (AMPCS) for the command and telemetry interface to the ground station can directly inherit the PAD capability

- The AMPCS AUTO interface and the general approach taken by SMAP AUTO can be applied to other missions, but the SMAP AUTO implementation is project specific.
  - This is not unexpected as the AUTO implementation must account for:
    - Project specific routine tasks to automate
    - Project specific telemetry to query (different dictionaries)
    - Project specific uplink products to build with different ground tools
    - Project specific light time / pass durations

Conclusion

- SMAP automation
  - Enables more responsive operations
    - Automation can be repeatedly executed with minimal effort from the operations team
  - Reduces potential for human error
    - Automation applies the same rigor every time it executes
    - Automation is never complacent, tired, distracted, bored, or needs training
  - Reduces workload associated with routine activities
    - Automation can handle routine commanding, reducing the workload on the team
    - Automation can handle commanding outside of prime shift
- Some aspects of this automation architecture can easily be applied to other missions, while some are project specific.
  - PAD, FNS, AMPCS AUTO all designed to be multi-mission
  - SMAP AUTO is a project specific implementation
- Gradual “phase in” of automation was both necessary and valuable.
  - Automation architecture required many tools, processes, and hardware to interact. Unfortunately not all of this could be simulated or checked in test configurations. The gradual introduction of automation allowed the team to establish confidence in the products that were being produced prior to autonomous uplink.