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Herschel & Planck Mission Data Systems

a Remarkable Collection of Challenges

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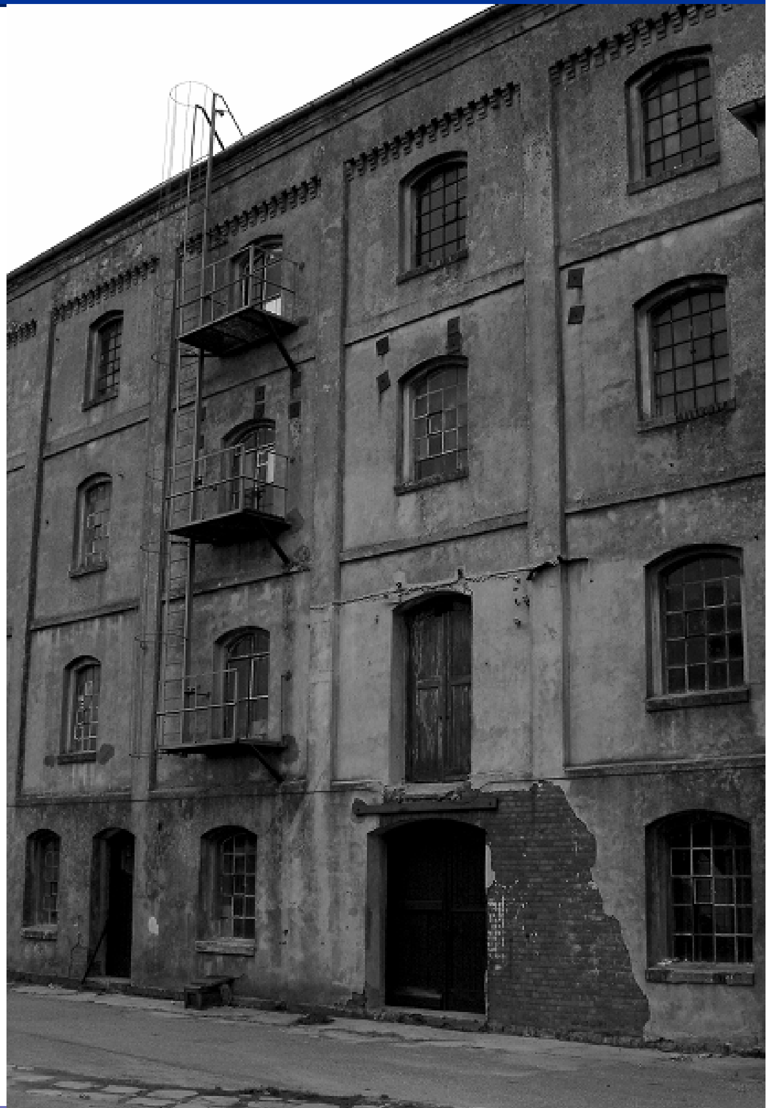
Outline

- Known Challenges
- Unknown Challenges
- Lessons Learned
- Conclusion



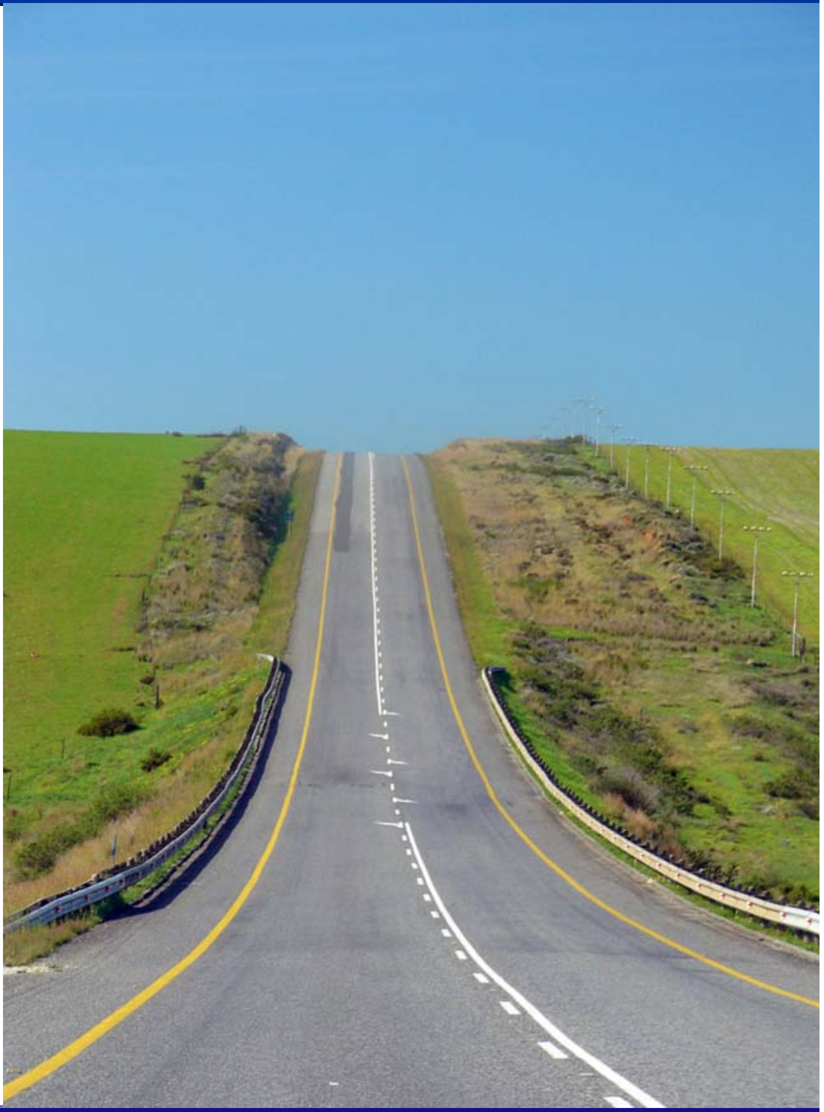
Outline

- Known Challenges
  - Introduction
  - Mission and Spacecraft features
  - Smooth Transition (3)
  - MCS Performance Demand (2)
  - SIM Performance Demand
  - MCS Infrastructure
  - SIM Infrastructure (Ground Models)
- Unknown Challenges
- Lessons Learned
- Conclusion

Known Challenges

Introduction

- Spacecraft Features
- Operability and maintainability for 5+ years
- Smooth Transition Concept
- Performance Demand
- Simulator Operating System W2000 Near End of Life; possible Porting needed



Known Challenges
Spacecraft&Mission Features

- Spacecraft (with 2x ERC32 @ 14 Mips) and instruments designed for autonomous operations by on-board schedule (Master Time Line)
  - Very demanding for simulator to run two emulators in parallel
- Large on-board storage
  - 8 GB accessed directly as RAM by on-board software
    - Impacts simulator resources and performance
  - Higher storage rate and access rate than previous missions
    - Impacts MDSs performance
- Short contact window (single 3-hour daily contact per spacecraft) and near RT Science
  - High telemetry downlink data rates (1.5 Mbps)
    - Short turn around time to process TM. Very high processing requirements on MCS
    - Impacts performance of simulated ground equipment

Smooth Transition

- Theory

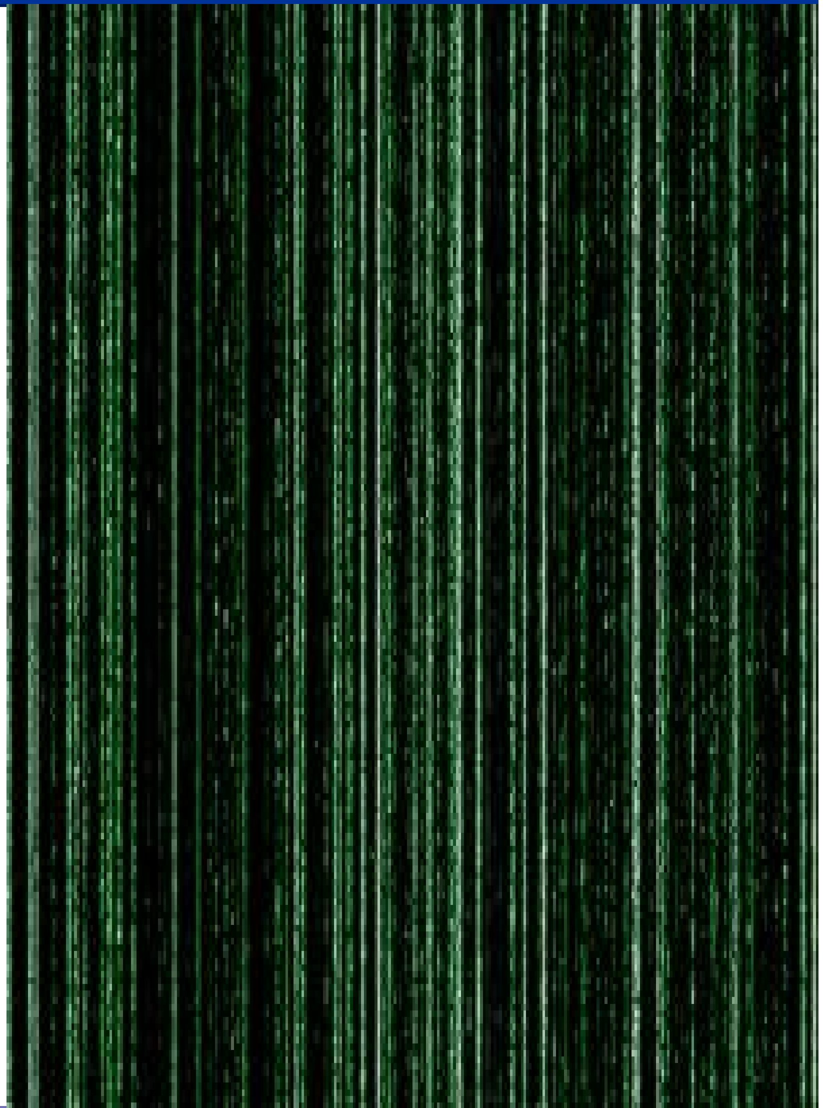
  "reuse and share rather than develop throughout ground segment"

- Implemented through Adoption of S2K by all GS parties
  - Centralised SDB shared among different, diverse project entities
  - Reuse of EGSE Central Checkout System (CCS) Software (S2K based)
  - Single OBSM shared across the project

Known Challenges

Smooth Transition :: OBSM

- Original objective was to have a single OBSM development and to share the functionality (and costs) across the H&P elements (e.g. PI and instrument developers, EGSE, operations)
- 12 months development at very early stage in project life cycle (before the MCS development was started)
- Considerations
  - Imposed a discipline in finalising the requirements in the OBSM area, which is often lacking requirement stability
  - Backwards compatibility issues limited the utilization in the early phases. OBSM D3-M01 Version (S2K 3.1 based) taken by the EGSE
  - Initial limited usage by PI's since provided functionality not fully needed at early project stage. PI's will start using it when required.



Smooth Transition :: CCS

CCS (Central Checkout System) based upon S2k infrastructure 2.3e with database extensions

- Initial aim was to reuse CCS as basis for the HPMCS development
- CCS was installed at ESOC
  - for evaluation/familiarization
- Conclusions
  - MCS has need to follow infrastructure evolution
  - CCS addressed the majority of the H&P MIB customization. This was retrofit into S2K
  - Capability to support automated tests included into HPMCS requirements

Performance :: MDS

- The missions and spacecraft characteristics imposed high performance requirements on both MCS and Simulator
  - MCS: Risk of too high server load for TM processing/distribution and archiving
  - MCS: Risk of too high client load problems
  - Simulator: Two ERC-32 processors (CDMU and AOCS) to be emulated

In all above cases → severe operability problems

Known Challenges

Performance:: MCS

MCS Telemetry Processing requirements

- Space Ground downlink rate 1.5 Mbps
- Ground Station to MOC bandwidth 1 Mbps shared between H & P

	Data on Board Gbps	Downlink rate kbps	Packet Size (bytes)	MCS ingestion requirement	Processing required at MCS Monitoring	Archiving	Distribution
VC0 Essential HK	0.05	5	22	real-time	Y	Y	Y
VC4 Routine HK	0.25	24	300	real-time	Y	Y	Y
VC1 RT Science	0.47	130	800	real-time	N	Y	Y
VC2 SSMM HK	2.5	1471			Y	Y	N
part 1 Service 1 packets			22	parts 1 and 2 ingested within 1 hour of VC2 dump start.	Y	Y	
part 2 Service 5 Events			300	the rest to be processed within 6 hours	Y	Y	
part 3 Service 5 Events			400		Y	Y	
VC3 SSMM Science	11.23	1471	700	to be processed within 10 hours	N	Y	N

Performance:: MCS

- TM Processing

  – Key performance factor for the processing and distribution was the TM packet rate impacted by the burst of Service 1 data ingested when visibility is acquired (DTCP 12 mins of VC2 part 1 at 700 packets/sec)

  – On the server side (the CPD) and on the client the cache were at the our major concern since we were far above the infrastructure specs (S2K 3.1 spec is 300 packets/sec)

Performance:: MCS

- Archiving
  - Key performance factor for the archiving was the TM packet rate where the potential bottleneck is disk I/O
  - It was expected that H/P packet rate peaks can be offset during periods of less intense archiving activity
    - Rosmex MCS (on SUN/Solaris) has been validated for up to 300 packets/sec
    - CCS (on PC/Linux) validated for 200 packets/sec (could support more)
    - Radarsat MCS (on PC/Linux) supports up to 2000 packets/sec

Known Challenges

Performance:: MCS

- Evaluated options
  - Separation of archives on different disks (application level control vs. RAID)
  - Integrate S2K 5.0 new archive supporting 1000 packets/sec
    - Depends on S2K and H/P schedule compatibility

Known Challenges

Performance:: MCS

- Start consideration of Linux platform as potential solution to all problems in one go

- Benchmarking provided following results
  - Performance tests performed under DSTF supervision
  - CPU performance (Hz) was identified as the prime factor in application performance
    - Processing about 3X faster on PC Linux (~to clock speed)
    - Archiving: better performance
    - Retrieval: about 2X faster

- …. We moved to Linux Servers

Known Challenges

Performance:: Simulator

- Early tests showed that real-time performance not achievable with two ERC32 processor emulators on 32-bit platform
- Emulator tested on new 64-bit architectures (Itanium, AMD)
  - High emulator performance on 64-bit platform with good margin
- Subsequently new machines 32-bit became available with high performance and multi-CPU
  - Test showed acceptable performance under 32-bit Windows
  - Stayed on 32-bit Wisdows on multi-CPU system
- OPS-GI and OPS-EC started support for 64-bit Linux
  - Tests showed performance very good on 64-bit platform
  - Move HPSIM to 64-bit Linux to get performance margin

Known Challenges
Infrastructure :: Ground Models

- Initial baseline was TMTCS used in sim due to
  - Performance concerns (high rate telemetry)
  - New SLE API (R-OCF) not supported on Windows
- Subsequently OPS-GI updated ground models to new SLE API
- Measurements showed that software ground model performance acceptable
- No need to use TMTCS
- Consequently, we avoided
  - Problems in operating extra h/w and complex configuration
  - Less costs

Outline

- Known Challenges
- Unknown Challenges
  - Consolidation and Distribution
  - Archive Redundancy
  - Uplink Demand
  - On Board Modelling
  - Efforts Estimates
  - SSMM size
- Lessons for future missions
- Conclusion

Unforeseen challenges
MCS Infrastructure :: S2K 4

- MCS move to latest version of infrastructure 4.x
  - HPMCS was one of the two pilots for S2K 4 integration
- Obviously effort required for integration however
  - Benefit from Linux line performance
  - Extended maintainability
  - Cooperation with infrastructure beneficial for faster convergence of S2K 4

Unforeseen challenges
Archive Redundancy :: MCS

- Requirements on Archive redundancy are derived from the OPS characteristics but as the relevance of our archive and disposition system grown in last decade

- Data Centre redesign implied few fundamental changes but the among the few a major one has impacted the failure recovery strategies because of the split of location

- In the early development Phase we have analysed possible solutions and the first one prompted was the RAPID technique

- The RAPID file approach provides optimal solution for archive synchronization

Unforeseen challenges
Consolidation and Disposition: : MCS

- Data Consolidation and Disposition
  - Initial Requirements resulted insufficient for Herschel-Planck real needs
    - Data stored onboard in many different packet stores, dumped at different times on different VCs, Source Sequence Counter not monotonic
    - Interpretation of requirements towards PI's changed
      - Reduced data delivery time (near-realtime consolidation)
    - Delivery control mechanism too rigid
      - Single APID-based consolidation window required
- Impact
  - Late revision of data consolidation requirements
  - Late redesign and extra cost

Unforeseen challenges

Uplink Rate:: MCS

- Herschel and Planck are in contact for 3 hours out of 24
  - On board activities are uplinked and executed via time-tagged commands
  - Some Herschel instruments commanded at low level. Mission Timeline gets very large
    - Example: Herschel Reference Mission Scenario MTL has 39200 TT TCs
  - Result: This stresses infrastructure beyond design limits

Unforeseen challenges
On-Board Models:: MCS

- HPMCS makes usage of a number of PUS services required then modelling on ground
  - On Board Queue Model representing the MTL(PUS Service 11)
  - On Board Event and Action Model modelling the list of detected events and applicable actions (PUS Service 19).
  - On Board Parameter Monitoring Model containing the list of parameters monitored on board (PUS Service 12).
  - On Board Control Procedure Model containing the list of flight procedures resident on board (PUS Service 18).
- The MTL Model is derived from the S2K OBQM and OBQD with some extension
- The others models are HPMCS mission specific

Unforeseen challenges

On-Board Models:: MCS

- Original requirements: The S2K OBQM and the initial versions of the HPMCS specific models are only updated with commanding information and real time telemetry causing immediate updates of the models. The model information can only be viewed from the dedicated displays in real time.
- Delta requirements: to handle playback telemetry as well, and the displays are updated to allow retrieval of past time model information.
- Delivery of delta due in June 2008
- Results: another huge new development late in project lifecycle

Unforeseen challenges
Effort Underestimate:: MCS

- The MCS developer dramatically underestimated the effort required for one of the subsystems.
- Actions: decoupling from main development, re-planning
- As the work is performed under FFP limited cost impact. However management overhead and significant schedule impact.
- Lessons Learned: Systematic comparative review of the subsystems pricing is instrumental for identifying and managing such risks already at evaluation/negotiation phase

Unforeseen challenges

SSMM size:: SIM

- Solid State Mass Memory very big (4 Gbytes)
  - 32-bit operating system cannot address whole SSMM in RAM
  - Breakpoint needs to copy 4 GBytes from one disk file to another
  - Consequently, breakpoints slow (v-e-r-y s-l-ow) on 32 bit
  - Solution: move to 64 bit platform to keep all data in RAM
- New machines
  - Simsat infrastructure available on SLES 9 SP2
  - Linux SP2 not supported on new h/w
  - Infrastructure port and validation needed for higher Service Pack level

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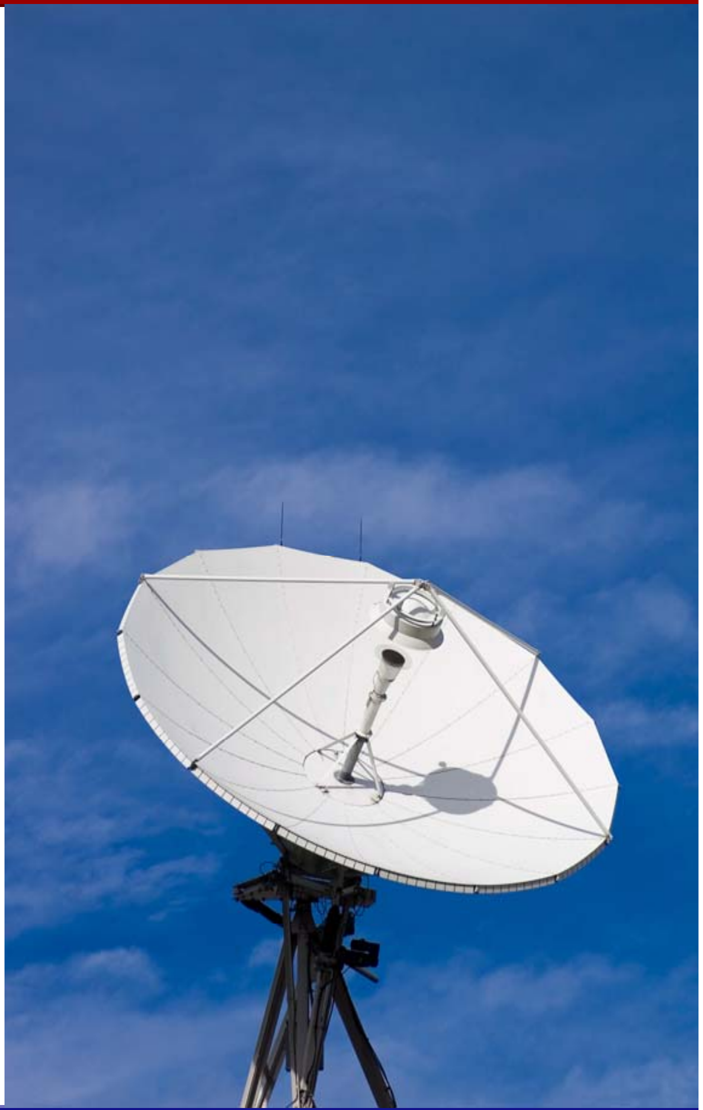
- Lessons Learnt
  - Technical Improvements
  - Process Improvements
- Conclusion



Lessons

Improvements:: Tech

Herschel RMS MTL (39200 TCs)

Operation	Duration	
	SUN/Solaris	PC/Linux
Load on Stack	6’ 15’	1’43”
Uplink	3^{h} 1’	1^{h} 3’18”

Other measurements

Operation	Duration	
	SUN/Solaris	PC/Linux
DB Import	6’20” H 4’30” P	48” H 37” P
Application build	2^{h} 4’	2^{h} 7’

Lessons

Improvements:: Tech

- Good SIM Thermal Model
  - Improved & stand-alone model
  - Released as generic model (ThermalNETwork)
  - Passed to infrastructure OPS-GI
  - Maintained as free-standing Generic Model
- Good SIM model of Electrical Power System
  - Laws of physics implemented (power, voltage and current)
  - Design and code can be reused by other missions

Lessons Improvements:: Tech

- Automated testing
  - Old method was manual click/check numbers
  - Old method was “Unit testing delivered on request”
  - Now entire test plan (unit/integration/system) can be run every night
  - test report generated from automated testing

Improvements:: Tech

- Better tools to isolate simulator from SDB
  - Ability to import SDB tables directly
  - Configurable relationship between SDB parameters and sim variables – not code change
- Automated testing
  - Tests can refer to SDB items
  - Use engineering values, TCs and parameters
  - Easier for FCT to understand
  - More stable over time
- Tool to convert MOIS procedures into Javascript
  - Test written according users FCPs
    - Stand-alone tool that can be used by other missions

Lessons

Improvements:: Process

- Historically:
  - Dependency between simulator and mission schedules for the ICDs, OBSW, SDB
  - Provision of the OBSW typically end up on the critical path for the simulator
  - Impossible to perform end-to-end test without OBSW
- For HP:
  - No OBSW in first delivery (functional model)
  - Idea to use GETS instead of OBSW for Simulator integration.
    - GETS: Generic Onboard software.
- Instrument User Manuals late and incomplete
  - Wrote Detailed Design Document for FCT and (real) instrument teams to review
  - Described exact understanding, behaviour and TM/TC usage
  - Used engineering terms (TM & TC names from SDB, not UML)

Improvements:: Process

- The rates and volumes required by the MCS were clearly much larger than for any mission at that time. Details analysis was performed to produce a minute-by-minute example of the packet and data rate requirements.

- At the outset it was unclear if available platforms and infrastructure would support the H/P MCS and Simulator performance requirements. Benchmarking performed prior to bid.

- These known risk items were addressed before SoW and RFP cycle under direct Data System Manager lead. Advantage is acquisition of knowledge for better ITT/RFP specification and evaluation of proposals

Lessons

Improvements:: Process

- H/P has been together with GOCE the pilot for S2K 4.0. Usage of S2K 4.0 started before final acceptance of infrastructure

- Experience has confirmed
  - Mutual benefits for both infrastructure and missions at Centre level
  - That new infra versions stabilise faster
  - Alignment to latest infrastructure version beneficial if time and resources are available

- The approach to cooperate with GI for infrastructure validation has been formalised since

Improvements:: Process

- Measures taken for sim cost control:
  - No OBSW in first delivery
  - Integration testing via limited functional model of OBSW.
  - Late kick-off
  - Predict needs
    - Provision for 10 versions of flight software in FFP
- HP Sim < 10% increase despite 18 month delay in launch

Lessons

Improvements:: Process

- Historically: Simulator systems very complex. Uncertainty with simulator deliveries quality and compliance to expected functionality

- HP Sim: intermediate informal deliveries. Developers get earlier feedback which is retrofitted into development. ESOC has chance to steer development. Avoid Big-Bang

Outline

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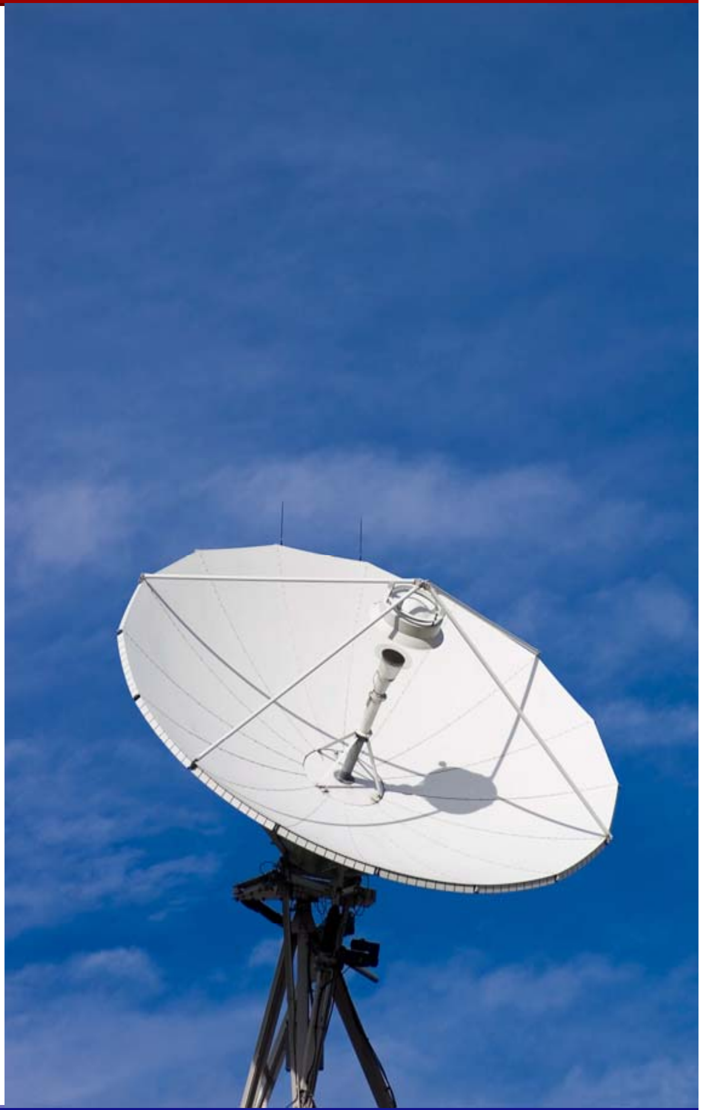
- Unknown Challenges
- Lessons Learnt
- Conclusion
  - MCS Status
  - SIM Status
  - Wrap up



Status Report:: MCS

- Successes:
  - 2 Missions served by 1 system
  - MCS on Linux
    - Gain in performance
  - Contribution to Smooth Transition
    - CCS reused as suitable
    - Single OBSM
  - Contribution to infrastructure S2K 4 consolidation
    - Maintainability
- Outstanding challenges
  - Completion of later developments
    - Consolidator
    - On-Board models

Status Report:: SIM

- Successes:
  - 2 Missions served by 1 system
  - Performance met
  - Improved thermal and power models
    - Contribution to infrastructure
  - Process improvement
    - Good risk and cost control
- Outstanding challenges
  - Validation of Linux version
  - Catch-up with payload changes

Conclusions

Wrap-up

- HP was a considerable challenge for the Mission Data Systems
- Some of the challenges were known, others weren’t
- The challenges have given impulse to new approaches both from the technical and process aspects
- The MDS developments are very advanced and most of the challenges have been successfully met
- We look forward to successfully completing the outstanding work