GSAW 2010

Migration from a legacy ground system to a state-of-the-art, COTS-based system:

Lessons learned from two recent programs

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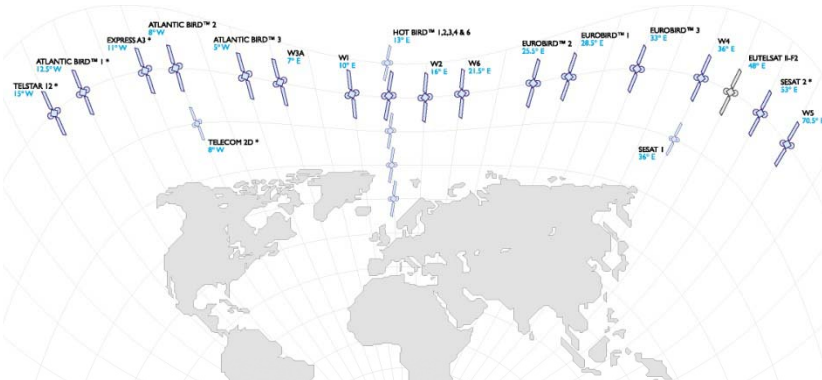
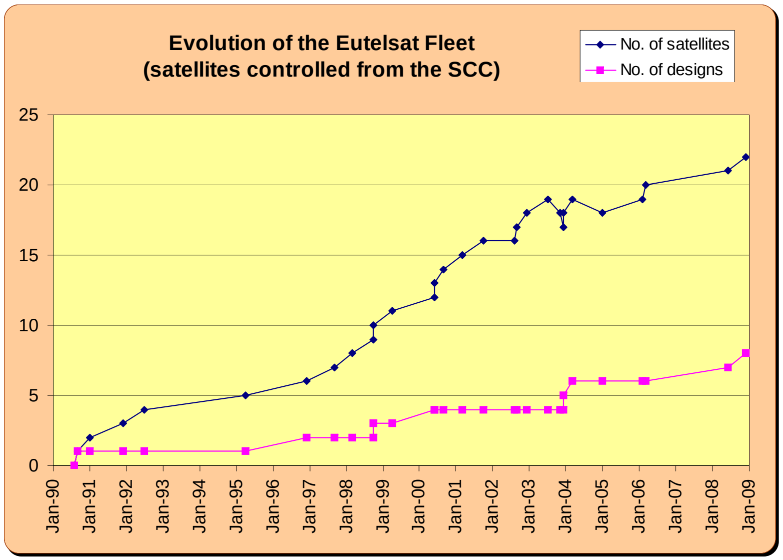
OVERVIEW

- Presentation analyzes the process followed to **migrate satellite fleet operations** from a legacy system to an **innovative** state-of-the-art, **COTS-based system**.
- Typical in **GEO** missions (life ~ 15+ years): obsolescence issues & high operations costs lead to replacement of ground elements or complete subsystems
- Must be carried out minimizing risks and with **no impact on operations**.
- We will discuss issues and **lessons learned** using as case studies two recent programs where GMV migrated operations of large fleets of GEOs

CASE STUDY #1: EUTELSAT FLEET MIGRATION

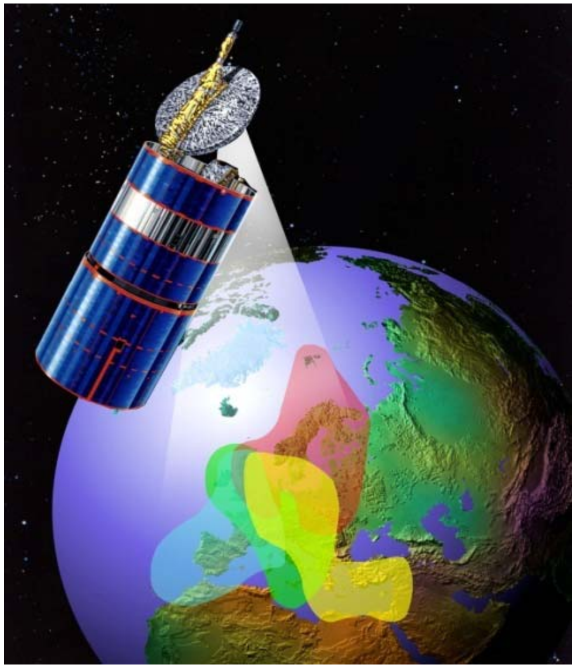
- EUTELSAT currently has a fleet of **24 geostationary satellites**
- **8 different satellite platforms** from 6 manufacturers (Thales, Astrium, Boeing, ISRO, Alenia, NPO/PM)
- Migration from legacy system to new system and addition of new satellites performed separately for Flight Dynamics System (FDS) and Real-Time System (RTS)
- Many **new satellites added** during migration process
- Long process, started in 2002





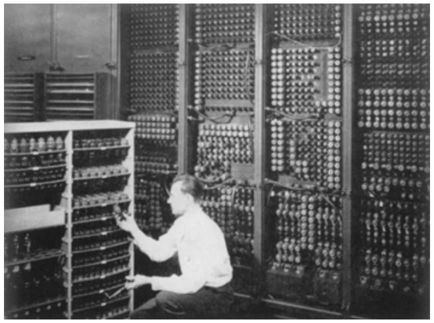
CASE STUDY #2: STAR ONE FLEET MIGRATION

- GMV migrated in 2008-2009 the operations of the ground system of Star One's Brasilsat B series fleet:
  - **4 Boeing BSS-376W** satellites operated from 2 sites
  - New state-of-the-art ground system with cost-effective software and hardware components
- GMV provided the **RTS** and **FDS**, plus:
  - Ground equipment monitoring & control (**M&C**)
  - Radiofrequency (**RF**) equipment
  - Baseband units (**BBUs**)
- Included **migration of operational procedures** and addition of long-term telemetry archive



REASONS TO MIGRATE GROUND SYSTEMS

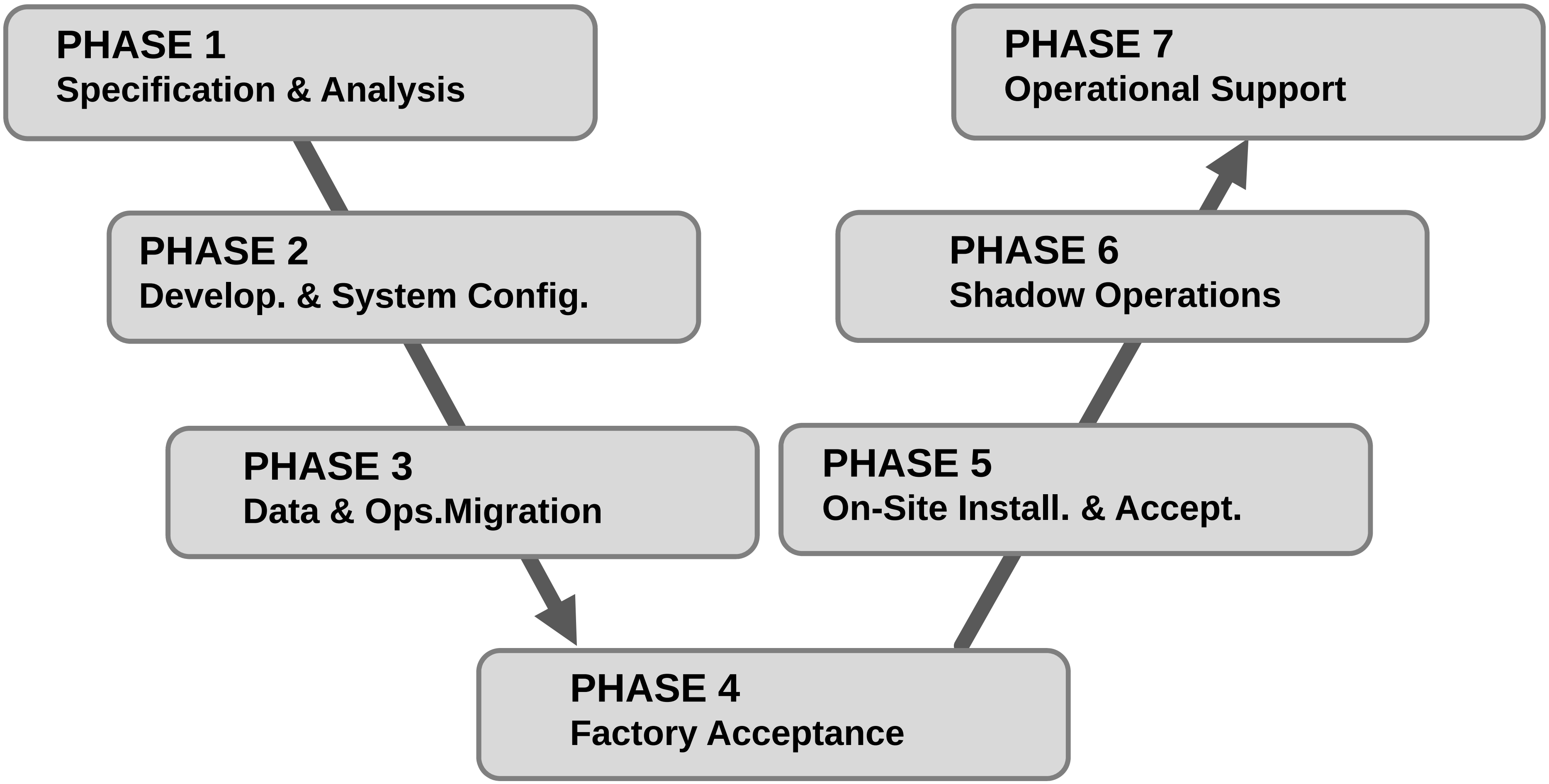
- Hardware or software **obsolescence**, serious issues with HW (servers, BBUs) and/or SW **availability and maintenance** (usually selected for the very first satellite of the fleet)
- Need/desire to **consolidate operations** into a seamless multi-mission system
- **Reduce total lifetime operations costs**
- Desire to take advantage of **modern technology**
  - Open architectures
  - Automation
  - Advanced telemetry archiving and broadcasting
  - New HW
- **Improve efficiency & reliability of operations**
- Safe and efficient collocation station keeping
- ... and many more



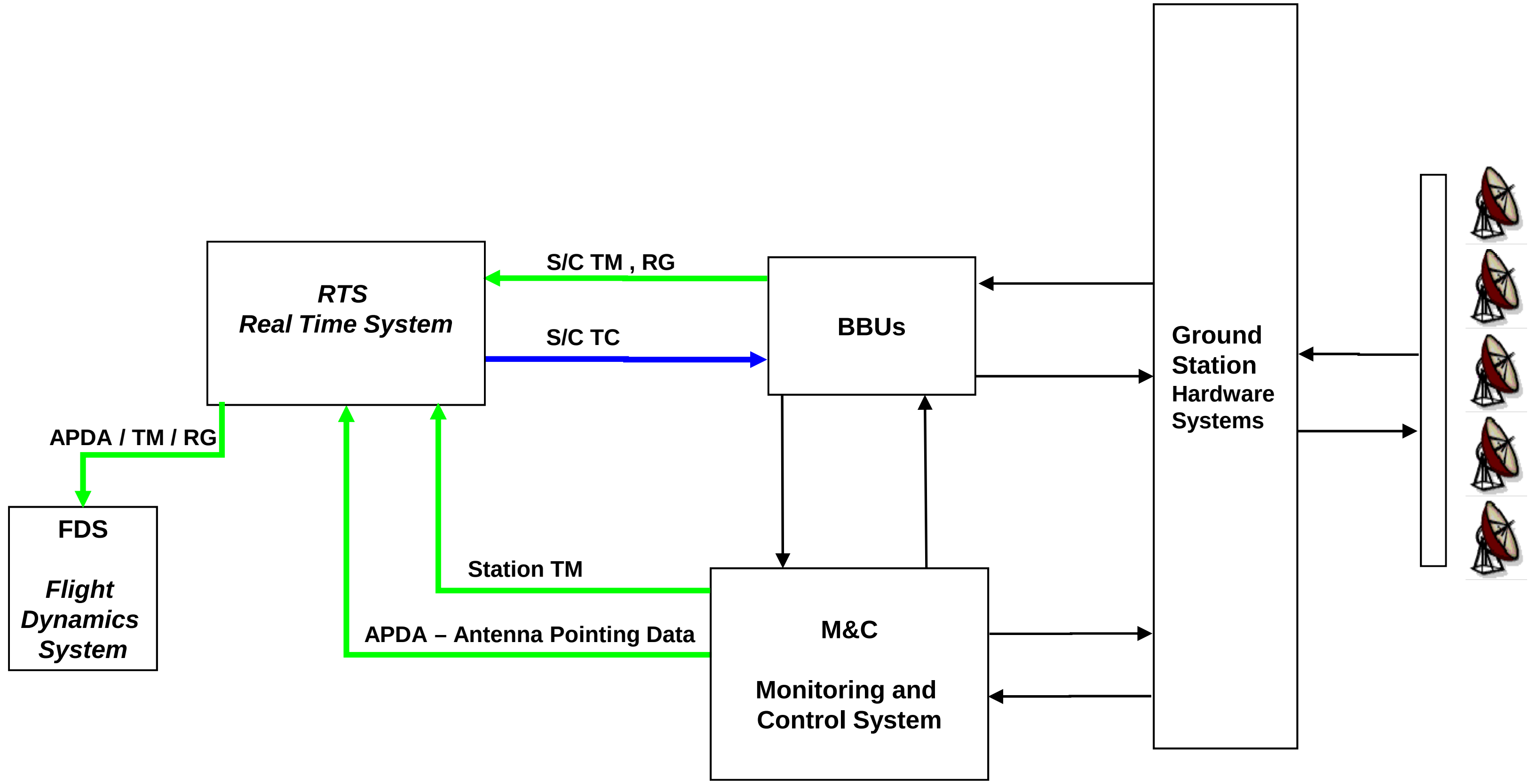
A TYPICAL REQUIREMENT IN MIGRATIONS

The new system shall do everything that the legacy system does (faster), plus a lot more

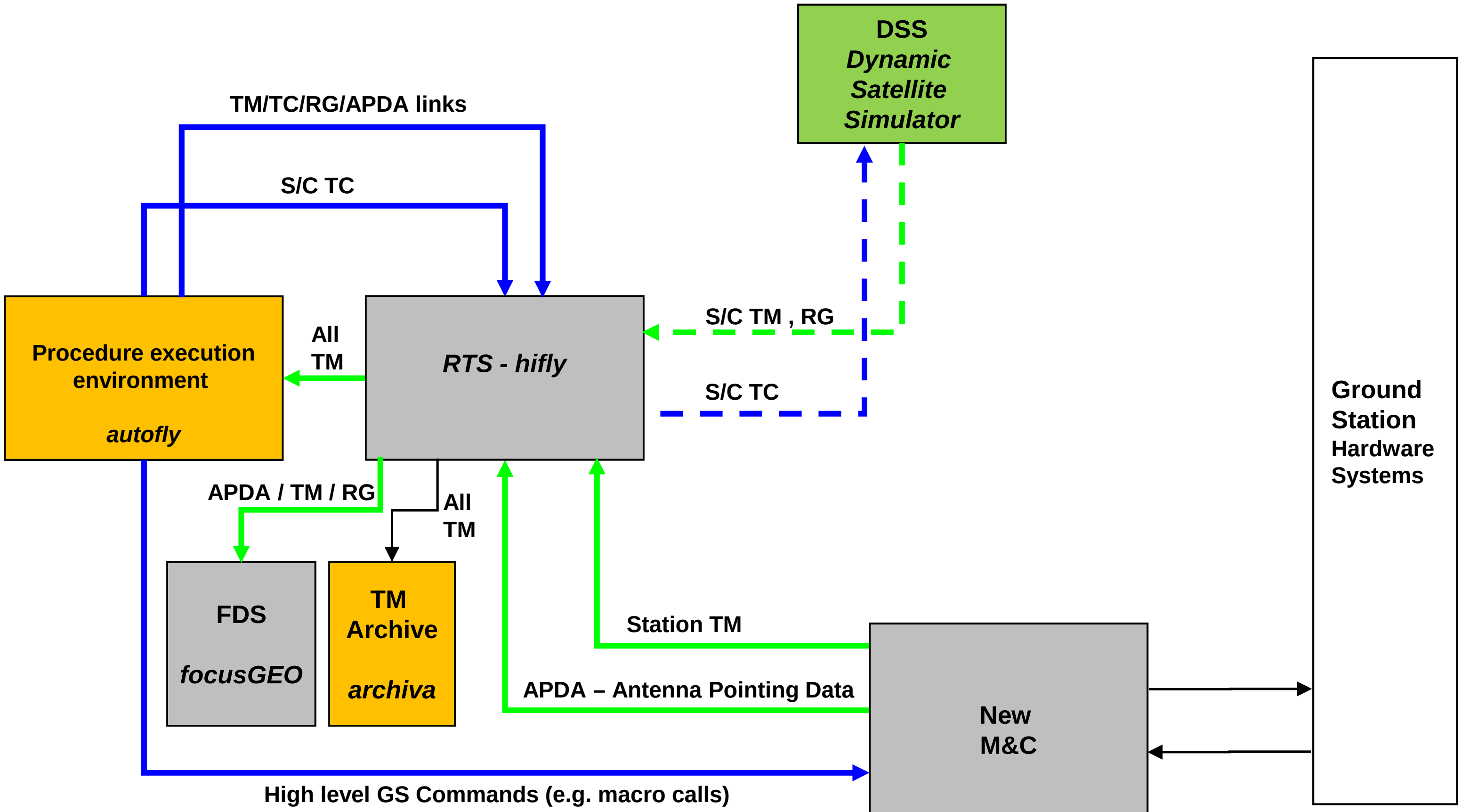
TYPICAL MIGRATION PROGRAM



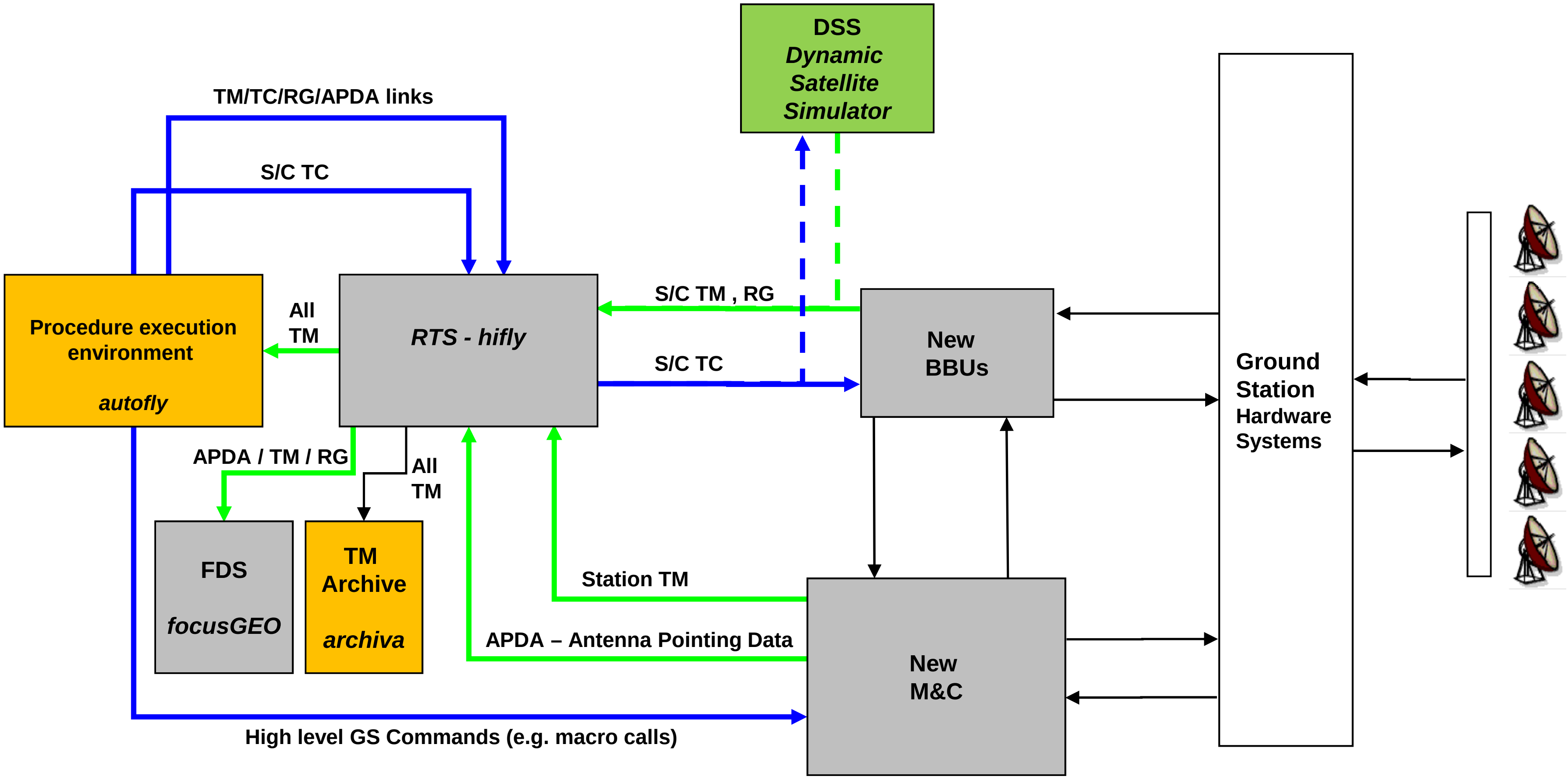
SYSTEM ARCHITECTURE: LEGACY SYSTEM (FUNCTIONAL, SIMPLIFIED)



SYSTEM ARCHITECTURE: IN FACTORY NEW SYSTEM (FUNCTIONAL, SIMPLIFIED)



SYSTEM ARCHITECTURE: INSTALLED NEW SYSTEM (FUNCTIONAL, SIMPLIFIED)



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MIGRATION ISSUES / CHALLENGES (1/4)

Each of the above phases is plagued with difficulties. Some of the most notable are summarized hereafter (each could have a dedicated presentation):

- **Specification and documentation**:
  - Exiting system **documentation** is often not updated (to say the least)
  - There are numerous **non documented features** / adaptations that may become a critical issue during validation if not properly managed. Examples:
    - Derived TM parameters
    - FDS algorithms
- **Resistance to change:** Expose the operations team to the new system (through demonstrations and/or prototyping)

MIGRATION ISSUES / CHALLENGES (2/4)

- **Historical TM migration**:
  - – Data completeness and compatibility is a source of surprises. Detailed planning is required.
  - – Anticipate realistic space needs and transfer rates (for TM conversion tools)

- **Best strategy** for TM migration depends on many factors. It needs to include:
  - Data to be migrated: Raw vs processed TM
  - Validation is a critical task, which usually requires the development of ad-hoc tools for massive automatic comparisons between legacy data and migrated data.
- **Migration of derived/synthetic TM** parameters deserves a detailed analysis from start, including different aspects:
  - Migration of algorithms for the real-time generation
  - Migration of historical data
  - Validation. Differences caused by different factors. DSS may be needed to simulate special situations

MIGRATION ISSUES / CHALLENGES (3/4)

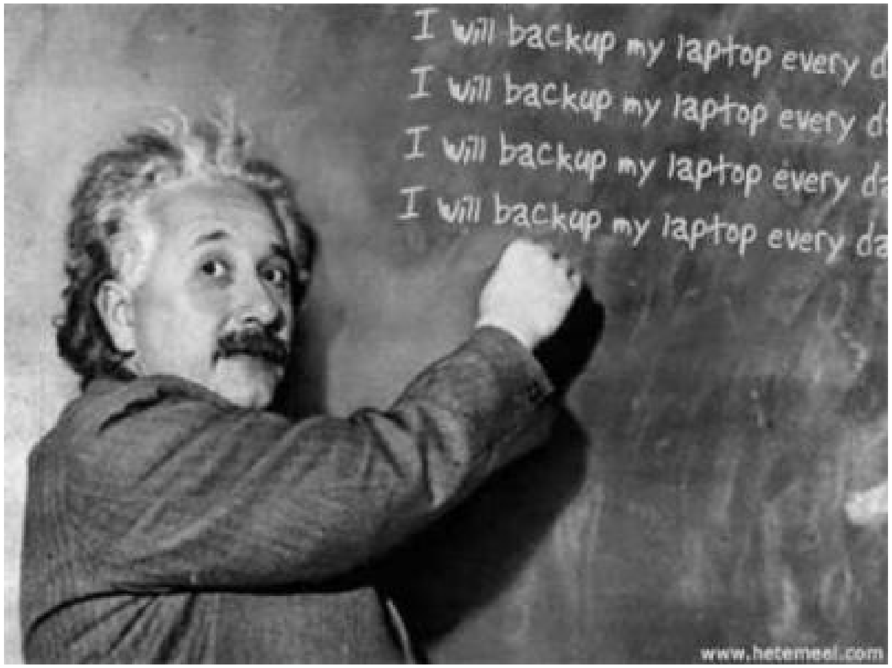
- **Flight operations procedures** migration is one of the most critical elements:
  - There might be paper procedures, semi automated, electronic (with versions), … this requires a very specific analysis and strategy to be agreed with the operations team
  - Use of an advanced, open, high-level language in the new system (e.g. Python) makes things a lot easier.
  - Validation can be very costly.
- **Training** sessions:
  - Must be very thorough and cover all satellite engineers and satellite controllers; and include a differ-ential analysis with the legacy system
  - Pay special attention to train the support team so that they fully understand the new system

MIGRATION ISSUES / CHALLENGES (4/4)

- The **shadow operations** phase needs to be adequately planned:
  - Make sure all necessary **facilities** are in place to support both systems running in parallel
  - Make sure the **operations team** is adequately manned to support shadow operations (it implies a heavy overload)
  - Anticipate tools to perform **data alignment**
  - Make sure that all **external interfaces** support shadow operations (dual compatibility and concurrent operations)

LESSONS LEARNED (1 / 3)

- A **very close collaboration** between the end customer and the industrial team is essential:
  - Allows complete understanding of the legacy system
  - Ensure a smooth transition
- The migration project needs being **adequately manned** by the customer
  - Too easy to underestimate



- Important to involve the end customer **operations team** deeply into the process
  - Involve ops teams (including stakeholders) into the process, not only SW support, and understand what is critical to operations,
  - But be careful of not ruining their involvement due to excessive testing / regressions

LESSONS LEARNED (2 / 3)

- Highly beneficial to schedule early **demonstrations** and **prototyping** for some elements:
  - Especially important for the migration of flight operations procedures
- Customer **specific operational concepts** have to be taken into account from start
- **Validation** is essential:
  - Requires early access to tools, such as the DSS, BBUs and encryptors
  - Validation procedures have to be **as close as possible to the operational usage** of the system to avoid problems when the system is operationally deployed
  - Perform **exhaustive factory** and **regression testing** before submitting the system to the operations team
    - The operations team are not ‘debuggers’
  - Provide **automated tools** to collect debugging information

LESSONS LEARNED (3 / 3)

- Very important to have **one baseband unit early** on site for testing, considering that
  - Many issues were resolved very early on the project schedule
  - Made the unit **fully compatible** with the satellite before final integration
  - Allow anticipated end-to-end tests with telemetry processing; synchronous and asynchronous telecommand; and T&C ranging
- Importance of custom, **high-fidelity algorithms for FDS** to guarantee the compatibility with the legacy system
- Value of **open, dynamic languages for procedures automation**
- Continuous, remote availability of the DSS valuable
  - Allowed development team multiple remote validation activities
  - Possible to simulate the end-to-end tests of the new system **before on-site installation**

Thank you!!

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BACKUP SLIDES

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GMV EXPERIENCE

cnes | esa | ETRI | EUMETSAT | INTA | इसरो isro | JPL | NASA | NOAA | ROSCOSMOS | USGS science for a changing world

Intelsat | eutelsat communications via satellite | SES ASTRA An SES GLOBAL Company | SES WORLD SKIES | SKY Perfect JSAT Corporation | عرب سات ARABSAT | hispasat | Star One una Empresa Embratel

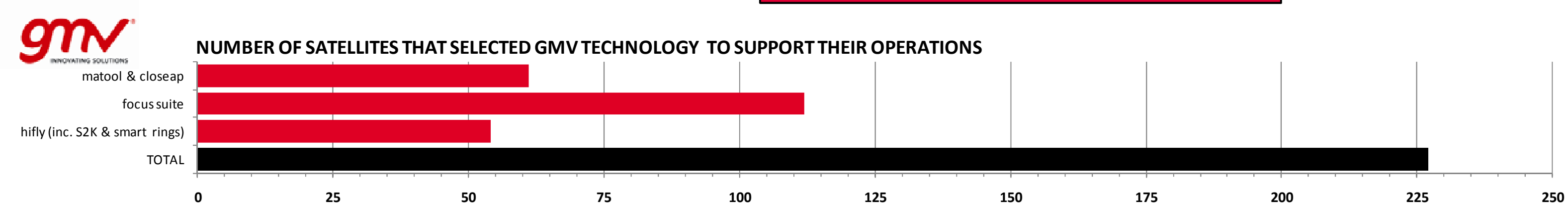
Globalstar | HELLASSAT | hisdesat | MEASAT | Nilesat | 'yes' OPTUS | SES SIRIUS An SES ASTRA Company | telenor | TELESPAZIO | TURKSAT | WORLDSPACE SATELLITE RADIO

BOEING | GENERAL DYNAMICS | HARRIS | Honeywell | LOCKHEED MARTIN | Orbital | Raytheon | SPACE SYSTEMS LORAL

EADS | OHB SYSTEM Ein Unternehmen der OHB Technology | RESHETNEV COMPANY | ThalesAlenia Space

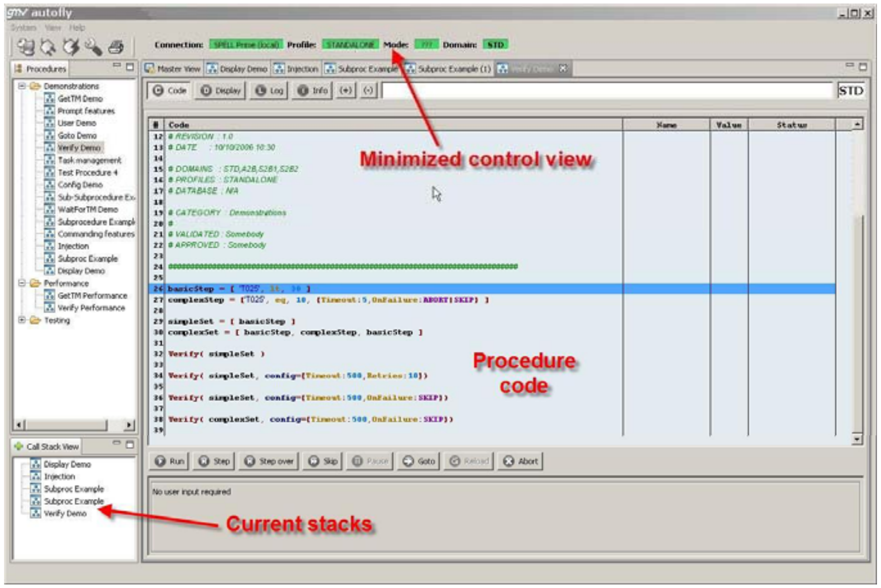
GMV has a long experience in the migraton of ground systems (Eutelsat, Hispasat, SES, Arabsat, Worldspace, StarOne & Globalstar) and deploying new systems.

NEXT USER'S CONFERENCE: Rockville, MD, Oct 2010



OPERATIONAL PROCEDURE MIGRATION (1)

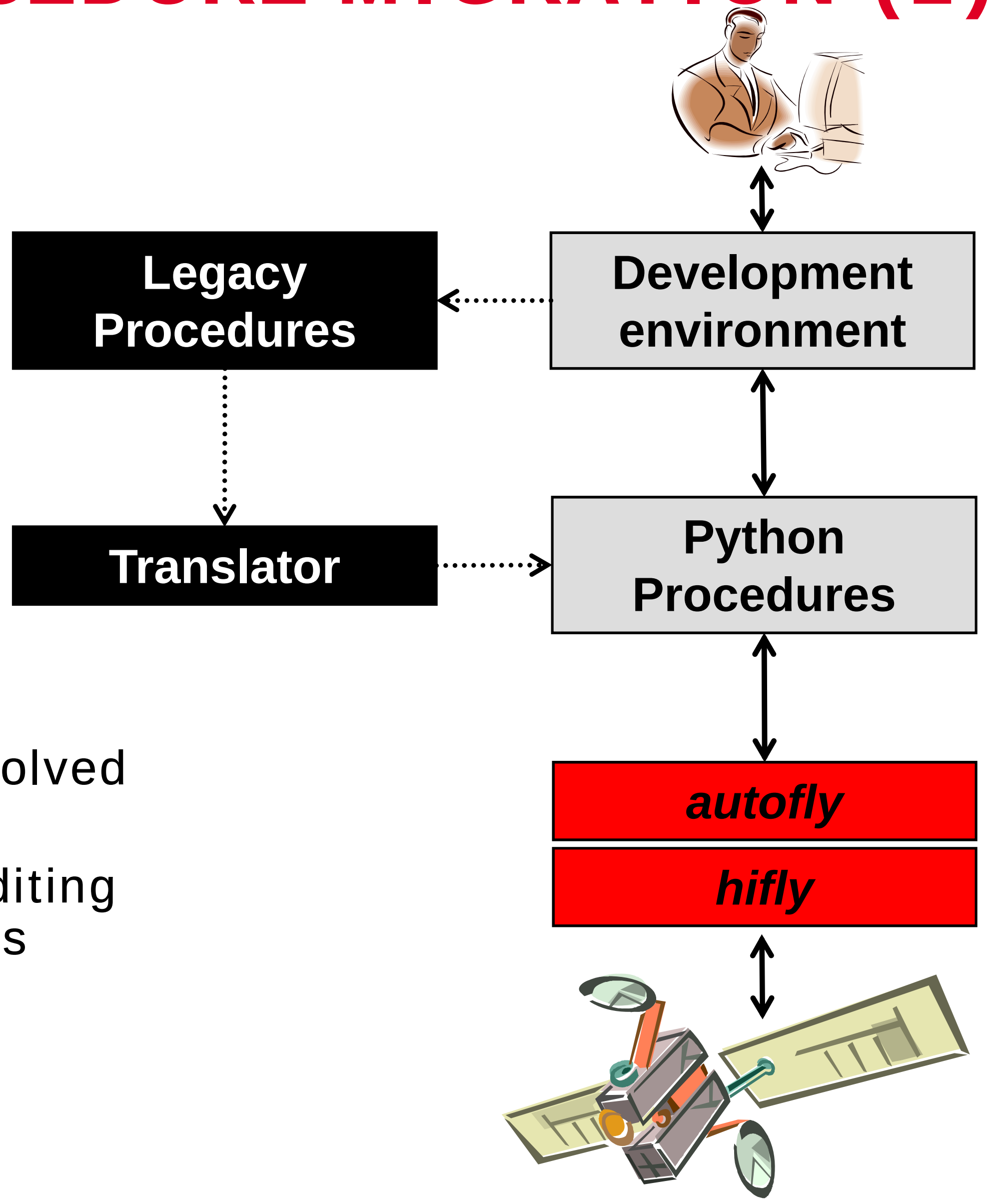
- In migrations performed by GMV automated procedures are normally converted to Python for use in ***autofly***
- ***autofly*** allows the operator to develop, test, modify, schedule and execute Python procedures, with:
  - Procedure execution
    - Parallel execution supported
  - Procedure control
    - Supports Step-by-step execution
  - Procedure monitoring



- ***autofly*** supports:
  - TM access and injection
  - TC injection and status monitoring
  - Event and out-of-limits access
  - Event injection
  - Modification of out-of-limit definitions
  - Open predefined TM displays
  - Display operator messages and prompt for input
  - Procedure nesting

OPERATIONAL PROCEDURE MIGRATION (2)

- A translator script is created to directly translate legacy code to Python:
  - – Avoid creating Python procedures from scratch
  - – Iterative process
    - – Testing the procedures
    - – Updating the translator
    - – Re-translating the procedures
  - – Repeated conversion issues solved in translation script
  - – Minimal amount of manual editing for one time conversion issues
  - – Assures traceability is easily maintained



OPERATIONAL PROCEDURE MIGRATION (3) VALIDATION STRATEGY

Step 1

Internal Error Reporting in Translation Script

- Invalid characters
- Unexpected logical constructs and arithmetic operators
- Incorrect syntax

Step 2

Automatic Validation of Python code in *autofly*

- Ensure Python code valid
- Sub-procedures called correctly

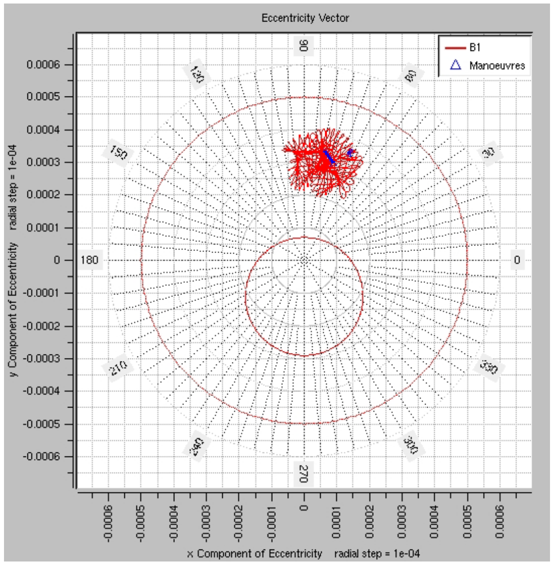
Step 3

Procedure Execution Against the Dynamic Satellite Simulator

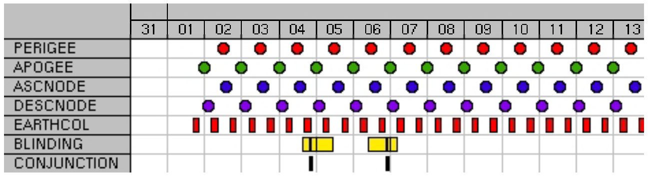
- All logical branches tested
- TCs recognized by the DSS and executed correctly
- TM values received, initiated execution of correct procedure
- Parameters updated
- Setting of system variables correct
- Sub-procedures initiated with variable values set

Python fully able to support the logic of legacy procedures

FLIGHT DYNAMICS MIGRATION



- Requires careful validation:
  - To guarantee algorithm consistency
  - To avoid any impact on operations
    - Precision of the orbit determination
    - Prediction of key orbital events
    - Achievement of the orbit control goals
    - Mass consumption
- Migration strategy:
  - ***focusGEO*** already supports most commercial GEO platforms
    - Reduces the risk of deficiencies in the platform-specific support
  - Close collaboration between FDS engineers from operator and GMV to identify and address function differences:
    - Reference frames
    - Dynamic models
    - Sun & Moon position prediction models
    - Maneuver planning strategies
  - A full year of operations needs to be simulated to analyze the impact of new station keeping strategy



ACRONYMS LIST

- APDA – Antenna Pointing Data Angles
- BBU – Base Band Unit
- COTS – Commercial Off-The-Shelf
- DSS – Dynamics Satellite Simulator
- FDS – Flight Dynamics System
- GEO – Geostationary Earth Orbit
- HW - Hardware
- M&C – Monitoring and Control
- RF – Radio Frequency
- RG - Ranging
- RTS – Real Time System
- S/C – Spacecraft
- TC – Telecommand
- TM – Telemetry