‘Test Like You Fly’ at APL

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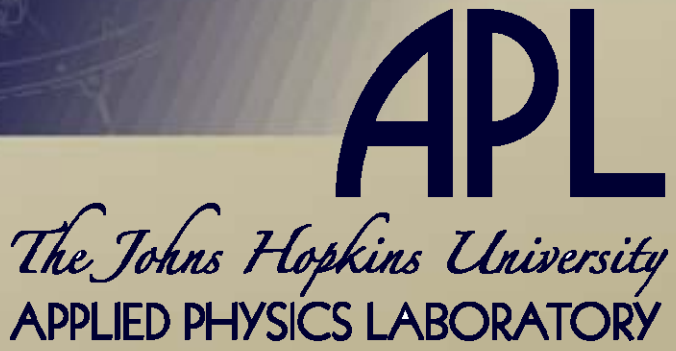

Agenda

- Introduction
- Mini-MOCs
- Mission Simulations ‘Like You Fly’
- Early Involvement of I&T and Mission Operations
- Limited cross-training of I&T and Mission Operations personnel
- Conclusion

Introduction

- **The ‘Test Like You Fly’ concepts discussed in this presentation are being used on the following NASA spacecraft: TIMED, MESSENGER, New Horizons, STEREO, and RBSP**
- **Each of these missions include ‘one of a kind’ spacecraft – i.e. the spacecraft bus is customized for each mission**
- **APL is providing cradle to grave support for each of these missions**

Mini-MOCs

- The Mini-MOC approach at APL is to use the same basic command and control software for bench level testing that is also used for Integration and Test (I&T) and Mission Operations
- Mini-MOC literally means that the bench level software is a subset of the MOC software
- The Mini-MOC approach was first used on the TIMED spacecraft - the approach was developed in 1997, the spacecraft was launched in 2001
- There were 4 Mini-MOCs on TIMED – Command and Data Handling (C&DH) subsystem, Guidance and Control (G&C) subsystem, GPS subsystem, and Avionics hardware subsystem

Mini-MOCs, continued

- A survey of TIMED users (conducted by the STEREO MOC Software Development Team) in May 1999 unanimously concluded that the Mini-MOC approach should be made available for future missions.
- A cost exercise conducted in February 1999 by the MESSENGER I&T lead concluded that the Mini-MOC approach that was used on TIMED would save the avionics developers somewhere between 15% to 33% of their ground support system development costs
- Mini-MOCs were used on STEREO, MESSENGER, and New Horizons
- RBSP conducted a trade study in 2007 as to whether or not to use Mini-MOCs, and the decision was made to use them

Mini-MOC Pros

- The command and telemetry definition database does not need to be translated or manually re-entered into the I&T database when the bench level testers deliver to I&T
- Some test procedures and display pages used during bench level testing can be reused for I&T
- It is easier for avionics, G&C, and flight software developers to support I&T and Mission Operations since they are already familiar with the command and control system
- Bench level tests can be automated through the Mini-MOC scripting capability
- In summary, by using the same system at bench level testing, I&T, and Mission Operations, the transitions between each of these phases are smoothed

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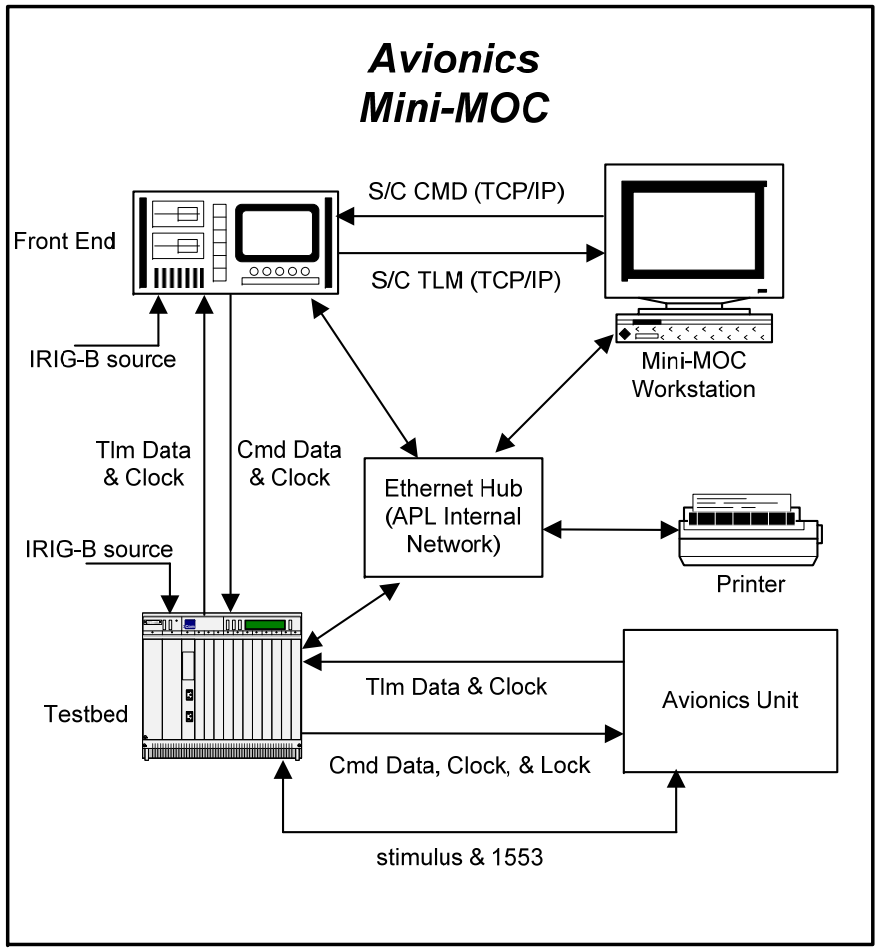
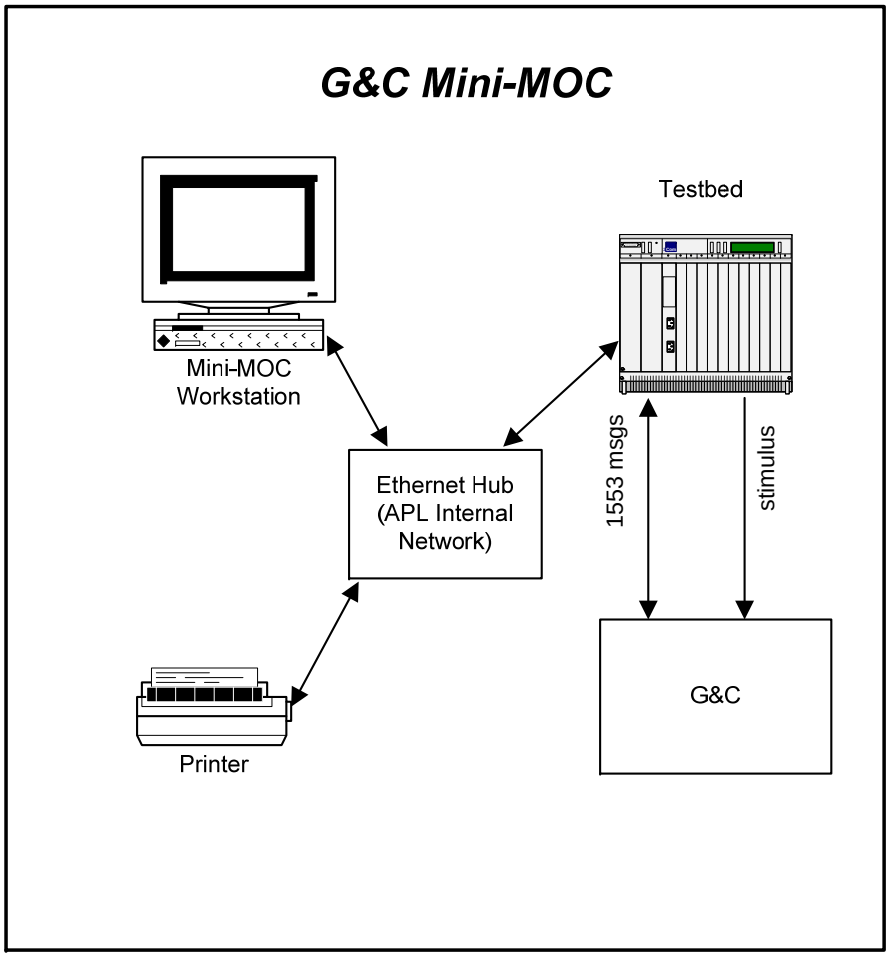
Mini-MOC Realities

- The IEM and flight software developers must use a generalized system rather than one that is written specifically for their application
  - This is a non-issue at APL since we also include customized testbed software and hardware in each bench level test area
  - The testbed software emulates the parts of the spacecraft that are missing during bench level testing. For example, in an avionics bench level test area the testbed software would emulate the instrument activity at the avionics/instrument interface
  - The testbed software also allows us to send “bad” commands to the C&DH software that cannot be produced (on purpose) by the Mini-MOC
  - The testbed hardware includes a breadboard model of the avionics unit

Mini-MOC Realities, continued





Mini-MOC Realities, continued

- **Bench-level test setups share a common command and telemetry definition database with each other, I&T, and Mission Operations**
  - **The organization of the command and telemetry definition database must have a “phase” or “scenario” concept to, for example, allow different alarms to be defined on a telemetry mnemonic for different phases of a mission**
  - **The command and telemetry definition database system and its associated configuration management plan must include methods that allow fast changes during bench level testing such as flight software developer telemetry definition changes vs. deliberate changes via a configuration control board during I&T and Mission Operations**

Mini-MOC Realities, continued

- **Mini-MOC hardware and software procurements and development must occur very early in a program in order to be ready in time to support bench level testing**
  - **NASA missions typically have 6 phases:**
    - **P: Proposal**
    - **A: Requirements definition and concept development**
    - **B: Preliminary design**
    - **C: Detailed design**
    - **D: Fabrication, integration, and test**
    - **E: Mission Operations**
  - **Initial purchases to support the Mini-MOC approach are usually made during Phase B**

Mission Simulations 'Like You Fly'

- Simulations designed to test the end-to-end mission operations system
- All mission simulations are run from the MOC regardless of the current location of the spacecraft
- Mission simulations include MOC, Science Center, Instrument, and Navigation team participation
- Some tests are run with the spacecraft, some are run with the spacecraft simulator
- Spacecraft level testing includes 4 mission simulations (all run with the spacecraft):
  - Once spacecraft bus is complete
  - Once full spacecraft (bus + instruments) is complete
  - Once during thermal vacuum testing
  - Once at the launch site

Mission Simulations 'Like You Fly', continued

- In simulations the spacecraft is fooled into thinking that it is flying through simulated sensor data
- For two spacecraft missions, both spacecraft participate
- Day in the Life (5 days long planned for RBSP)
- Special tests
  - Launch
  - Separation
  - Early operations
  - Maneuvers
  - Contingency operations (including anomalies injected via the simulator to test the Mission Operations team)
  - Software loads

Early Involvement of I&T and Mission Operations

- In our APL Space Department missions, we typically include an I&T Director and a Mission Operations Manager in all phases of the mission, including the proposal phase
- The I&T Director's responsibility early in a program is to ensure, whenever possible, that the spacecraft being designed can be properly tested before launch
- The Mission Operations Manger's responsibility early in a program is to ensure, whenever possible, that the spacecraft being designed can be operated efficiently and successfully

Limited Cross-training of I&T and Mission Operations personnel

- It is not unusual at APL for some of the members of the I&T team, especially operators, to join the Mission Operations Team (MOT) after launch. This activity raises the practical experience level of the MOT.
- APL MOT members often specialize in an area of the spacecraft, such as a Guidance and Control specialist or a Power subsystem specialist. It is not unusual for such a specialist to aid in the I&T of their particular subsystem. This increases their knowledge in their specialty and aids I&T.
- This cross-training is facilitated by the fact that the same command and control system is used in both I&T and Mission Operations.
- We have learned that there this cross training needs to be limited, with a core I&T team and a core Mission Operations team that is not involved in cross-training.

Conclusion

- **‘Test Like You Fly’ is alive and well in the APL Space Department, aided by our use of Mini-MOCs, extensive Mission Simulations, early involvement of I&T and Mission Operations, and limited cross-training of I&T and Mission Operations personnel.**
- **We feel that this approach increases efficiency and decreases errors in bench-level testing, I&T, and Mission Operations.**