Autonomous Real Time Requirements Tracing
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Outline

• Introduction
• AFTS Test Bed
• AFTS SRS
• Auto Procedures to Flight Software
• Tracker Sequence
• Timeliner Coding Standard
• Configuration Management
• Summary
Introduction

• Autonomous Mission Operations (AMO), part of NASA’s Advanced Exploration Systems (AES) Program, is using inter-center cooperation to develop new technologies and techniques to enable deep space exploration with an emphasis on procedure development and execution.

• The Autonomous Fluid Transfer System (AFTS) uses Draper Labs supplied Timeliner-TLX software for command, control, and planning for top level execution and monitoring.
AFTS Test Bed

- The AMO team designed the AFTS Test Bed as a means to demonstrate Autonomous command and control capabilities.
AFTS Test Bed

![Diagram of AFTS Test Bed]

- Tank 1
- Tank 2
- Recirculation Pump
- Three way valve
- Filter
- MV4
- Primary
- Backup
- Pump 1
- Pump 2
- G1
- G2
- V1
- V2
- V4
- F1
- F2
- F3
- P1
- P2
- P3
- P4
- P5
- P6
- Data/Pwr
- Controller
- Free flow Leg
- Return Leg
- Primary Backup Free Flow Leg
- Return Pump
- H1
- H2
- T1
- T2
- F3
AFTS SRS

- 5.1 %AAFTS-0001 The software system shall be capable of performing quarter tank fluid transfers over the primary flow path with a single crew action.
- 5.2 %AAFTS-0002 The software system shall be capable of performing quarter tank fluid transfers over the backup flow path with a single crew action.
- 5.3 %AAFTS-0003 The software system shall be capable of performing quarter tank fluid transfers over the return flow path with a single crew action.
- 5.4 %AAFTS-0004 The software system shall be capable of performing half tank fluid transfers over the primary flow path with a single crew action.
Auto-Procedures to Flight Software

- Auto-Procedures will be a “must use” for deep space missions with communication delays.
- Currently, Auto-Procedure development does not require Software Requirement Specifications or Software Detail Design documents.
- Only validation of testing required is from peer review and test plans/results showing all paths of execution have been tested.
Auto-Procedures to Flight Software

- Timeliner-TLX proven with use on-Board ISS for payload and core cadre operations (proven reliable commander and flight qualified).
- Timeliner-TLX was selected and used for the Autonomous Mission Operations Autonomous Fluid Transfer Test-bed (Intelligent procedures with embedded FDIR).
- Timeliner-TLX chosen for ISS AMO EXPRESS experiment (Single commanded EXPRESS Rack activation and de-activation).
Auto-Procedures to Flight Software

• With the advancement of intelligent auto-procedures, auto-procedures move into the realm of flight software
• Flight Software must meet NASA Software development and engineering requirements
• The Tracker capabilities will assist in qualification for this movement of auto-procedures to flight software
Tracker Sequence

- Software Requirements Specification (SRS)
- Timeliner Compiler Listing Files (TLL)
- SRS / Timeliner Parser
- Requirement Tracer File (TLS)
- Compiler
- Timeliner TLL
Tracker Sequence

1. Bundle Active
2. Sequence Active
3. Range within Sequence Statement
4. Record Requirement Encountered

Install Tracker Bundle/Sequence
Install Test Bundles

Exection Cycle
Tracker Sequence

- **Sequence TRACKER** Active
- **---***
- **---*** We start our control loop to monitor every second
- **---***

**Every 1.0 then**
- **---*** First we scan the HAL_MAIN Bundle
- If AWTS_HAL_MAIN.BUNSTAT = BUN_ACTIVE Then -- Is the bundle active?
  - If AWTS_HAL_MAIN.Initialize.SEQSTAT = SEQ_ACTIVE Then -- Is the Initialize Sequence active?
    - If AWTS_HAL_MAIN.Initialize.SEQSTMT IN 25..38 then -- Current line number within the req range?
      - Message "GAFTS-0001 Manual Valve Status Query Requirement"
    - End If
  - End If
  - If AWTS_HAL_MAIN.Initialize.SEQSTMT IN 56..81 then -- Current line number within the req range?
    - Message "GAFTS-0006 Autonomous Procedure Installation Requirement"
  - End If
- End If
- End If
- End If
- **---*** Next we scan the Safety Bundle
Timeliner Coding Standard

-- GAFTS-0001 Manual Valve Status Query Requirement
25 confirm "HAL: Are the Manual Valves One and Two in the On Position?"
26 when RESPONSE_RECEIVED WITHIN 1:00 then -- Crew one minute to respond
27 if OPERATOR_RESPONSE = AFFIRMATIVE THEN
28 MESSAGE "HAL: AFTS Test Bed is Ready for Operations!"
29 Set ReadyForOps = TRUE
30 else
31 WARNING "HAL: AFTS Test Bed is Not Ready for Operations!"
32 Set ReadyForOps = FALSE
33 end if
34 otherwise
35 disregard "HAL: Manual Valve Inquiry timeout!"
36 WARNING "HAL: Automatic Bundle Installation Inhibited"
37 Set ReadyForOps = FALSE
38 end when
-- GAFTS-0001 Manual Valve Status Query Requirement
Configuration Management

- ------ TRACKING TAG : 1304031037540151
- 13 04 03 10 37 54 0151
- YY MM DD HH MM SS Version

- ------ BUNDLE NAME: AWTS_HAL_MAIN
- ------ BUNDLE USER INFO:
- ------ BUNDLE EXECUTION SIZE (BYTES): 2508

- ------ VERSION: TLX 5.1
- ------ FILE:     MSLSRC/AWTS_HAL_MAIN.TLS
- ------ COMPILER OPTIONS:
- ------ NETWORK:  txnetwork.txt
- ------ TIDB:     TIDB/
- ------ MSLSRC:   MSLSRC/
- ------ MSLIBN:   MSLIBN/
- ------ MAX_BUNDLE_FILE_SIZE: 65536
- ------ DATABASE_SEARCH: GDB_ONLY
- ------ SQL_DATABASE_DRIVER: oracle.jdbc.driver.OracleDriver
- ------ SQL_DATABASE_URL: jdbc:oracle:thin:@localhost:1521:TLX
- ------ SQL_DATABASE_USERNAME:
- ------ SQL_DATABASE_PASSWORD:
- ------ MAX_BUNDLE_BUFFER_SIZE: 1000000

- ------ SEQUENCE 1: INITIALIZE
## Tracker log file

<table>
<thead>
<tr>
<th>TIME TAG</th>
<th>BUNDLE NAME</th>
<th>SEQUENCE NAME</th>
<th>TRACKING TAG</th>
<th>MESSAGE TEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>09/20/13 09:21:53</td>
<td>AWTS_HAL_MAIN</td>
<td>INITIALIZE</td>
<td>1309200832450151</td>
<td>HAL: Are the Manual Valves One and Two in the On Position?</td>
</tr>
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<td>09/20/13 09:21:55</td>
<td>REQUIREMENT_TRACER2</td>
<td>TRACKER</td>
<td>1309200917150151</td>
<td>GAFTS-0001 Manual Valve Status Query Requirement</td>
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<td>INITIALIZE</td>
<td>1309200832450151</td>
<td>HAL: AFTS Test Bed is Ready for Operations!</td>
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<tr>
<td>09/20/13 09:22:02</td>
<td>AWTS_HAL_MAIN</td>
<td>INITIALIZE</td>
<td>1309200832450151</td>
<td>HAL: Enter the Minimum Temperature (Degrees F) for the Supply Tank?</td>
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<td>HAL: Enter the Maximum Temperature (Degrees F) for the Supply Tank?</td>
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<td>GAFTS-0006 Autonomous Procedure Installation Requirement</td>
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<tr>
<td>09/20/13 09:22:31</td>
<td>AWTS_ECLSS</td>
<td>INSTALLATION ACKNOWLEDGED</td>
<td>1309191306550151</td>
<td>ECLSS Bundle Installed Initialize Sequence is Active</td>
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<td>TRACKER</td>
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<td>GAFTS-0006 Autonomous Procedure Installation Requirement</td>
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<tr>
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<td>AWTS_HAL_MAIN</td>
<td>INITIALIZE</td>
<td>1309200832450151</td>
<td>HAL: EC LSS Bundle installed</td>
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<tr>
<td>09/20/13 09:22:34</td>
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<td>EC LSS_INSTALLATION</td>
<td>1309191306550151</td>
<td>EC LSS: EC LSS Bundle Installed</td>
</tr>
<tr>
<td>09/20/13 09:22:35</td>
<td>REQUIREMENT_TRACER2</td>
<td>TRACKER</td>
<td>1309200917150151</td>
<td>GAFTS-0006 Autonomous Procedure Installation Requirement</td>
</tr>
</tbody>
</table>
Summary

• Tracker capability is unique to the Timeliner-TLX Language.
• The Autonomous Real Time Requirements Tracer provides real time code coverage.
• The Tracker Sequence can aid in program development by assisting hardware and software designers.
• Automates the software quality process that before was unreliable and difficult to test.
• Configuration Management is built into the Autonomous Real Time Tracer.
Acronyms

- AES – Advanced Exploration Systems
- AFTS – Autonomous Fluid Transfer System
- AMO – Autonomous Mission Operations
- SDD – Software Design Document
- SRS – Software Requirements Specification
- TLX – Time liner Executor