Autonomous Real Time Requirements Tracing
Outline

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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

Tank 1
- Recirculation Pump
- Three way valve
- Filter
- MV4
- T1
- H1
- P1
- Data/Pwr
- Controller

Tank 2
- Return Pump
- T2
- H2
- P6
- Data/Pwr
- Primary
- Backup
- Free Flow Leg
- Pump 1
- Pump 2
- G1
- V1
- P2
- G2
- V2
- P4
- P5

Recirculation Pump Three way valve Filter MV4 Return Pump

Primary Backup Free Flow Leg Pump 1 Pump 2 G1 V1 P2 G2 V2 P4 P5

Controller Data/Pwr Tank 1 Tank 2

NASA
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

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

Ejection Cycle

Install Test Bundles
Tracker Sequence

- **Sequence TRAC KER 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
          - 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
  - -- *** Next we scan the Safety Bundle
-- 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/
• ------ MSLOBIN: MSLOBIN/
• ------ 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>
<tr>
<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>AWTS_HAL_MAIN</td>
<td>INITIALIZE</td>
<td>1309200832450151</td>
<td>HAL: AFTS Test Bed is Ready for Operations!</td>
</tr>
<tr>
<td>09/20/13 09:22:02</td>
<td>AWTS_HAL_MAIN</td>
<td>INITIALIZE</td>
<td>1309200832450151</td>
<td>Enter the Minimum Temperature (Degrees F) for the Supply Tank?</td>
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<tr>
<td>09/20/13 09:22:13</td>
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<td>INITIALIZE</td>
<td>1309200832450151</td>
<td>Enter the Maximum Temperature (Degrees F) for the Supply Tank?</td>
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<tr>
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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_EC_LSS_ACKNOWLEDGED</td>
<td></td>
<td>1309191306550151</td>
<td>BUNDLE INSTALLATION</td>
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<td>GAFTS-0006 Autonomous Procedure Installation Requirement</td>
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<td>09/20/13 09:22:33</td>
<td>AWTS_HAL_MAIN</td>
<td>INITIALIZE</td>
<td>1309200832450151</td>
<td>HAL: EC LSS Bundle installed</td>
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<td>09/20/13 09:22:34</td>
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<td>INITIALIZE</td>
<td>1309191306550151</td>
<td>EC LSS: EC LSS Bundle Installed</td>
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<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 - Timeliner Executor