Supporting Tests of Autonomy: Autonomy Requirements Tester (ART)

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Topics

- SBIR and the ART project
- High-level Diagram
- Test Runner
- Requirements in XML Format
- Generating Test Plan from Requirements
- ART Examples
- Advantages
- Innovations
- Next Steps

NASA SBIR

NASA Small Business Innovation Research (SBIR) project titled "Autonomy Requirements Tester" (ART) with the following goals:

- Design eXtensible Markup Language (XML) **schema** to define data models to support app-level testing
- Describe potential approaches for **semi-automatic** test generation
- Design **displays** that support the management of requirements, test designs, and test results
- Develop a Concept of Operations **(ConOps**) for the use of ART that employs the following scenarios:
  - Capture autonomy requirements
  - Generate test specifications
  - Execute the test specs
  - Report results

Recent Survey

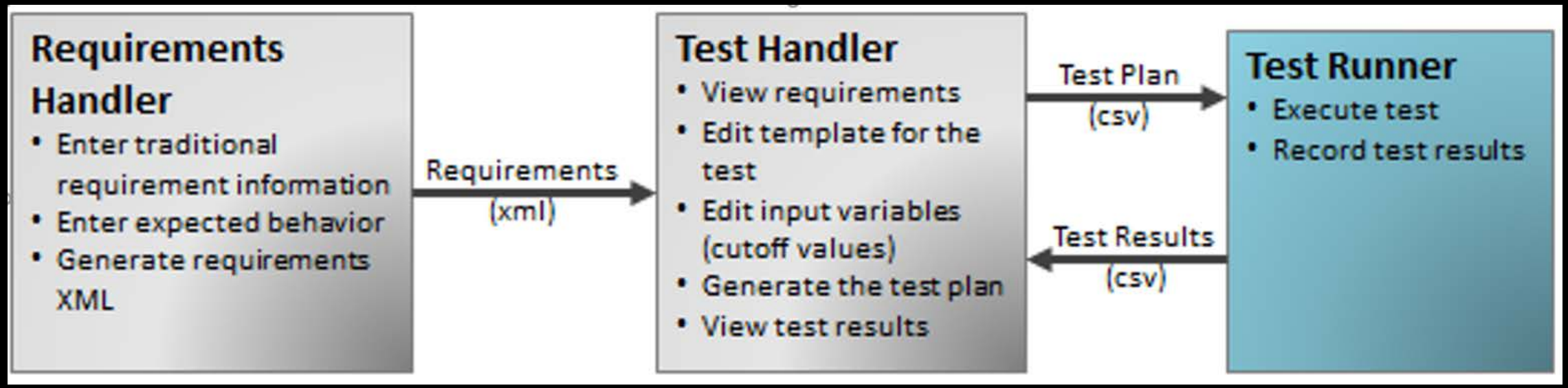
A recent survey of software developers reveled some of their top issues:

1. Requirements that are confusing or incomplete
2. Modifying software that is not documented, difficult to understand, or difficult to see the relationship between requirements and software
3. Unrealistic expectations or deadlines

- This SBIR project directly addresses the first two issues

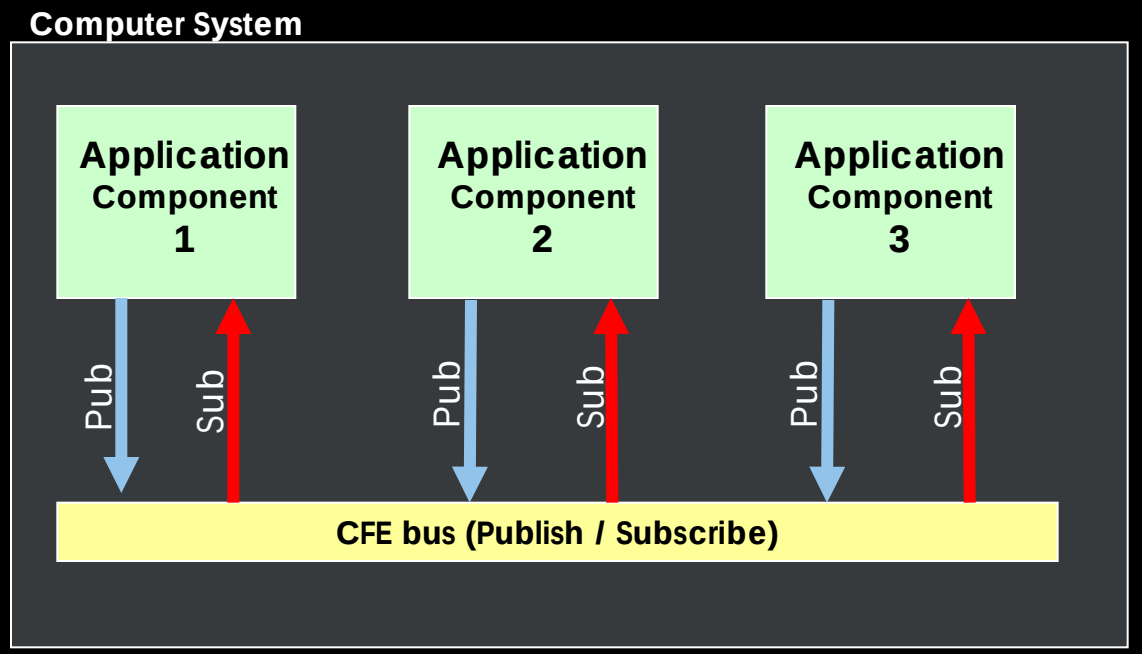
ART Flow Diagram

High-level diagram of Autonomy Requirements Tester (ART)



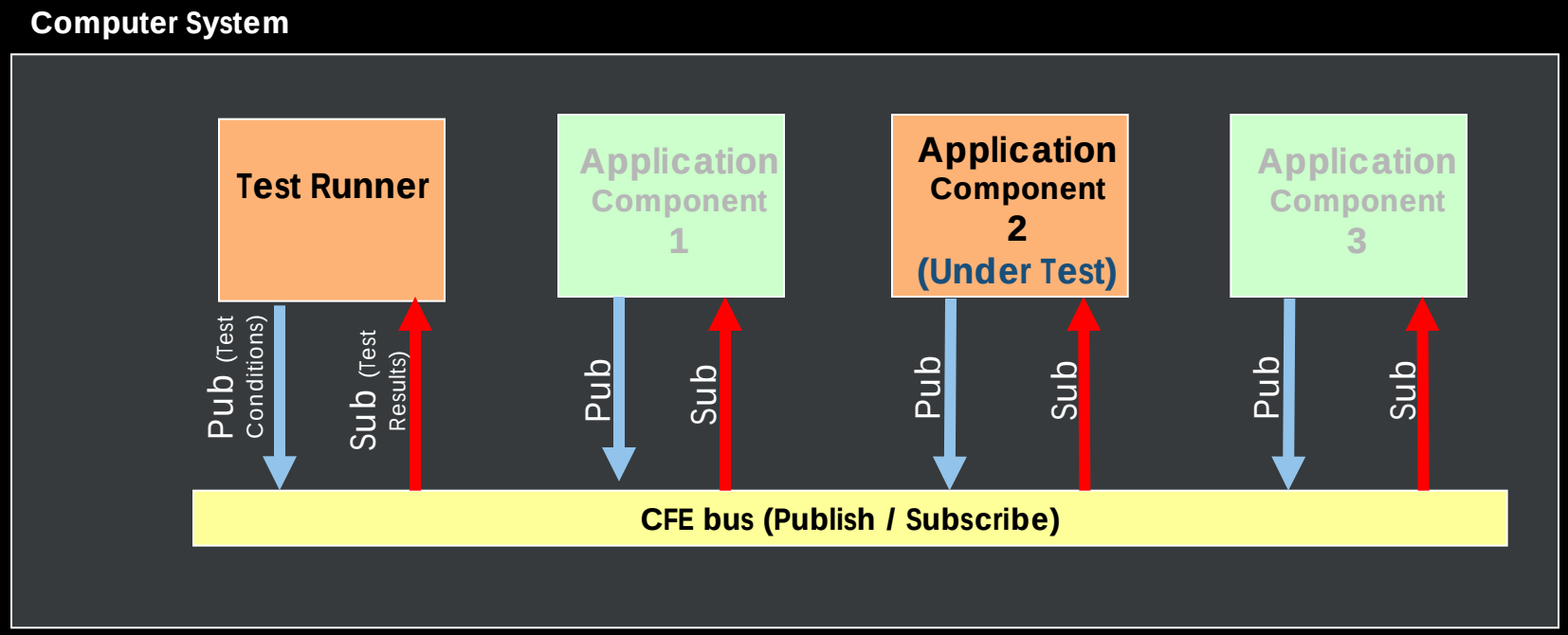
Publish / Subscribe Software

- Examples: cFS and ROS
- Component based design
- Publish-subscribe message communication to make component apps independent



Test Runner Software

- **Publish**: Send specific test data to Application Under Test
- **Subscribe**: Receive test results from Application Under Test



Test Runner: Reads Test Spec, Produces Test Results

Test Spec (Script Data)
(Adaptation of ATML)

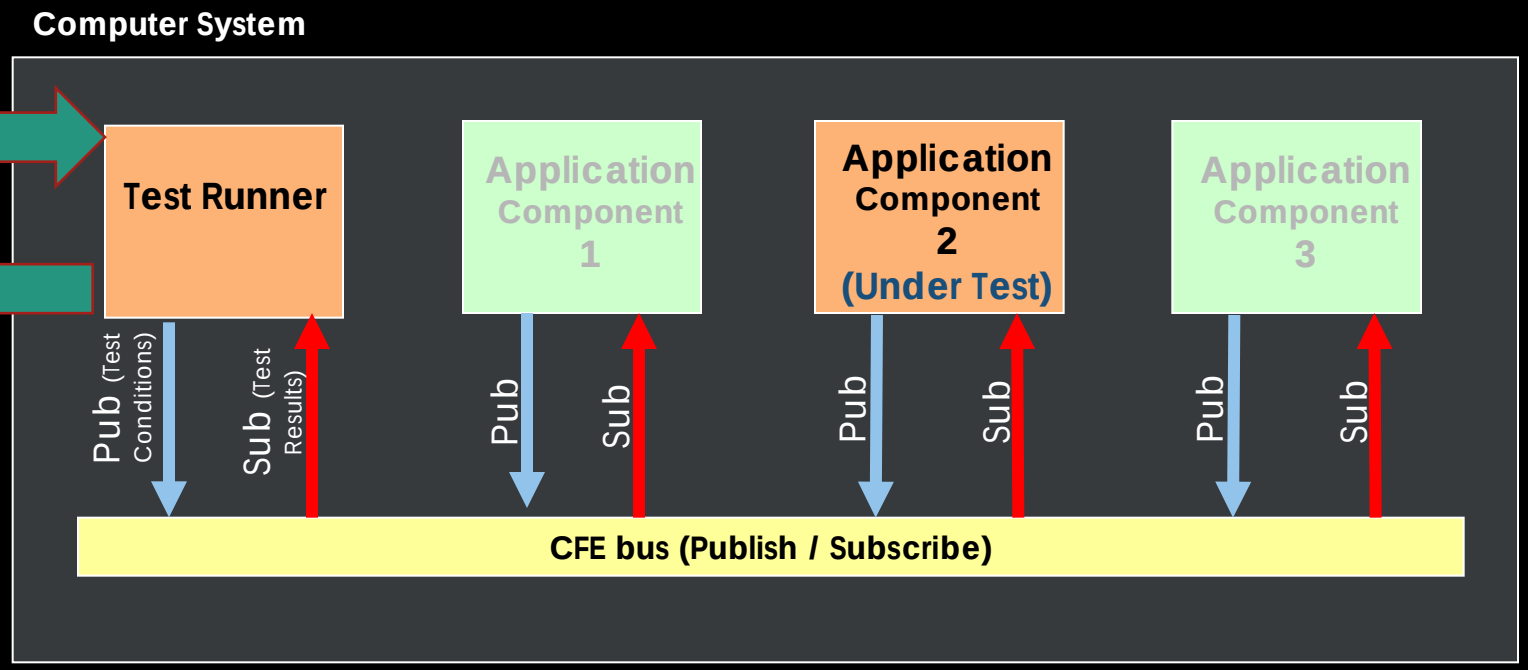
```
Test1
Input Message:
        x=5
        y=2
        z=7
Expected results
message:
        xx=1
        yy=3
        zz=1

Test2
...
```

Test Results

```
Test1
<pass>

Test2
Expected
        xx=1
        yy=3
        zz=1
Observed
        xx=0
        yy=3
        zz=1
...
```



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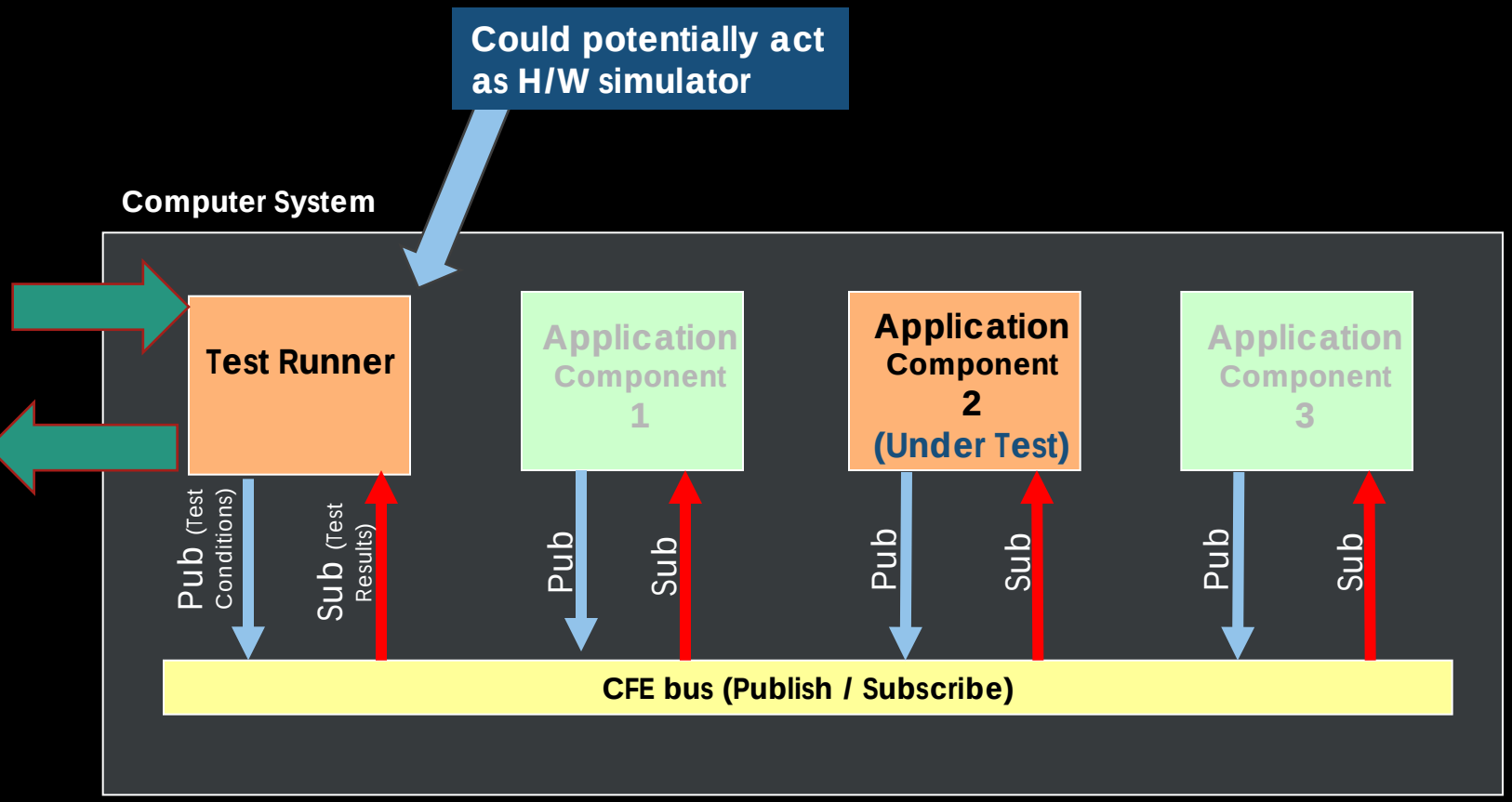
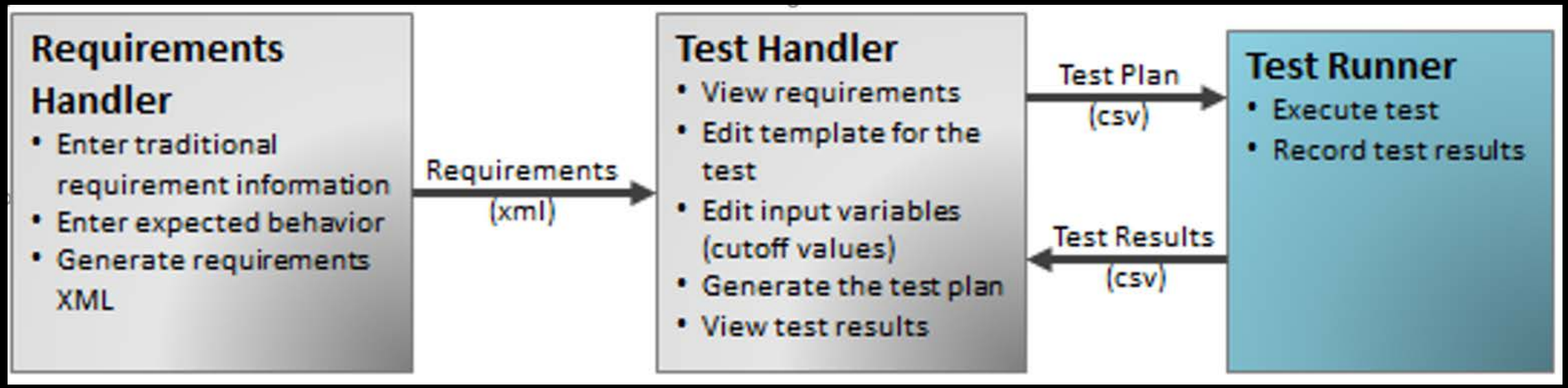


ART Flow Diagram

High-level diagram of Autonomy Requirements Tester



Requirements in XML format

Requirements

AUT-3	Monitor Battery Temperature	Autonomy shall perform the following tiered response if the battery temperature is above a pre-defined limit: A) Soft-reset the PSC B) Power-cycle the PSC C) Switch the PSC (via a CIM side switch)

Behaviors

- **No action should be taken if Battery temp okay**
- **All data needs to have consistent readings over a period of time such as 5 of 6 readings must be the same**
- **There is a limit to the number of times a command can be sent to the hardware**

XML Requirements

Generate Test Plan From Requirements

Observation from Solar Probe Plus autonomy requirements:

- Similarities from one requirement to the next
  - Often a tiered response, when first tier doesn't correct the issue, go to the next tier
  - Rule based behavior: If {condition} then {response}
- Similarities enable the formation of **a template** that could be reused for generating tests
- Some additional parameters are needed in addition to the template. A **display** was developed to collect this data.

Template For Generating Test Specification

AUT-3	Monitor Battery Temperature	Autonomy shall perform the following tiered response if the battery temperature is above a pre-defined limit: A) Soft-reset the PSC B) Power-cycle the PSC C) Switch the PSC (via a CIM side switch)

1. Set nominal spacecraft system state
2. Verify autonomy takes no action
3. Inject fault
4. Verify faulted state (optional, especially level 0)
5. Verify autonomy response
6. Repeat steps 3-5 through all possible iterations
7. For tiered rule:
    1. Inject fault corrected by 1st action
    2. Inject fault corrected by 2d action
    3. Inject fault corrected by 3d action
    4. Inject unrecovered fault

Data Entry To Enable Test Generation From Template

Enter Design Values To Construct Initial Test

AUT-3	Monitor Battery Temperature	Autonomy shall perform the following tiered response if the battery temperature is above a pre-defined limit: A) Soft-reset the PSC B) Power-cycle the PSC C) Switch the PSC (via a CIM side switch)

Enter values from design file ...

M 5 N 6 Persistence (m of n)

9 Max fire count

2 Priority

Enabled Initial rule state (enabled/disabled)

battery_temp Battery temperature variable name (default from rqts xml)

160 pre-defined limit

PSC_reset_cmd Soft-reset the PSC command name (default from rqts xml)

PSC_pwr_cycle_cmd Power-cycle the PSC command name (default from rqts xml)

change_CIM_side_cmd Switch CIM side command name (default from rqts xml)

XML Test Plan

Data Model Based on IEEE Standards

adopted by the Institute of Electrical and Electronics Engineers (IEEE) as a standard (IEEE Std 1671-2010)

Examples: Browsing Requirements

Autonomous Rule System Requirements Overview

Requirements | Test Plans | Test Results

Requirement ID	Title
AUT-1	Detect Loss of Telemetry
AUT-2	Detect Invalid Telemetry
AUT-3	Monitor Battery Temp
AUT-4	Monitor Battery State of Charge
AUT-5	Detect Critically Low State of Charge
AUT-6	Battery Heater Power On
AUT-7	Battery Heater Power Off

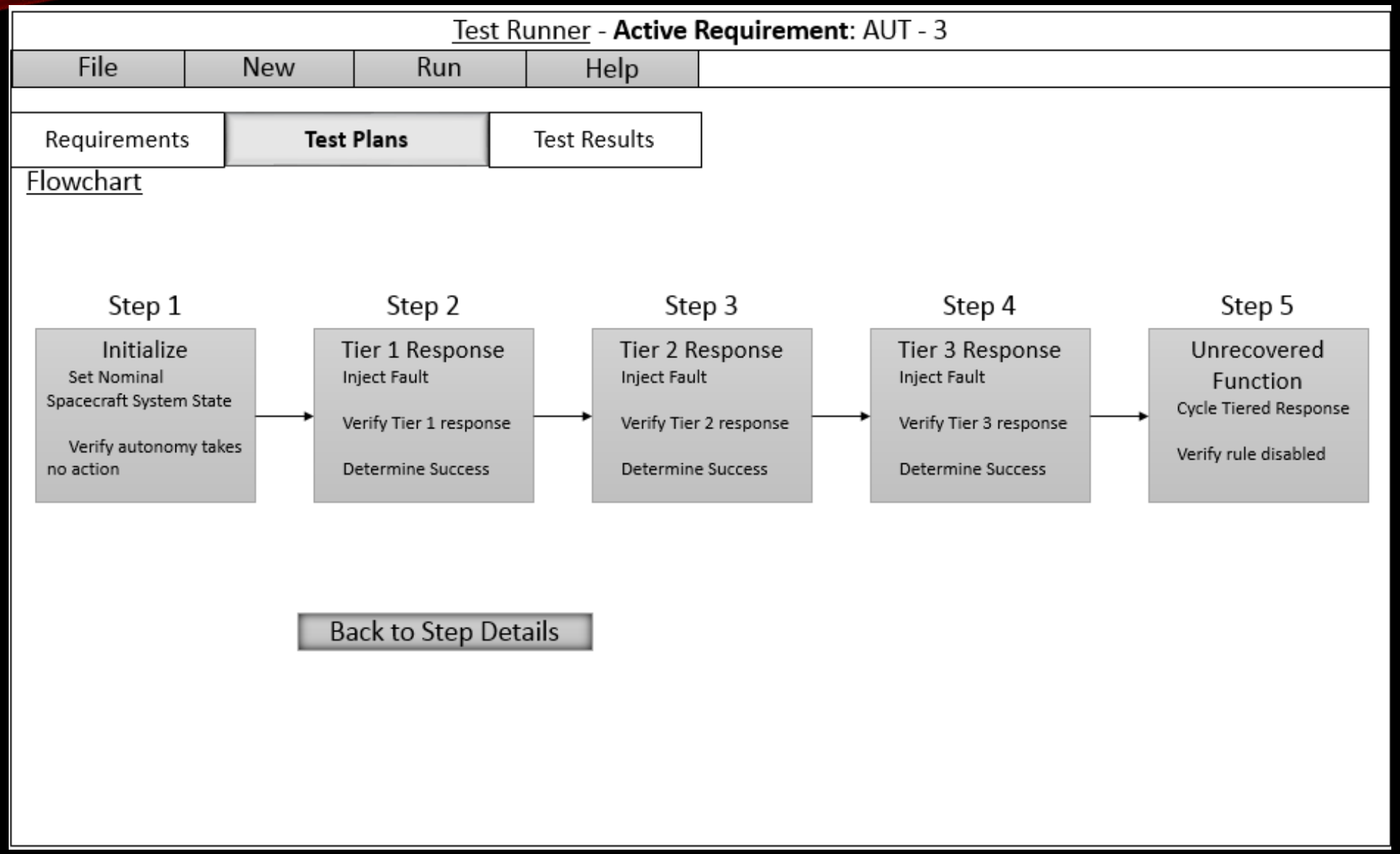
Requirement AUT-3 Monitor Battery Temp

ID	AUT-3
Name	Monitor Battery Temp
Categories	Device Health, Thermal Monitoring
Parents	SC-1
Rationale	Protects against a potential PSC control fault that could cause excessive battery temperature.

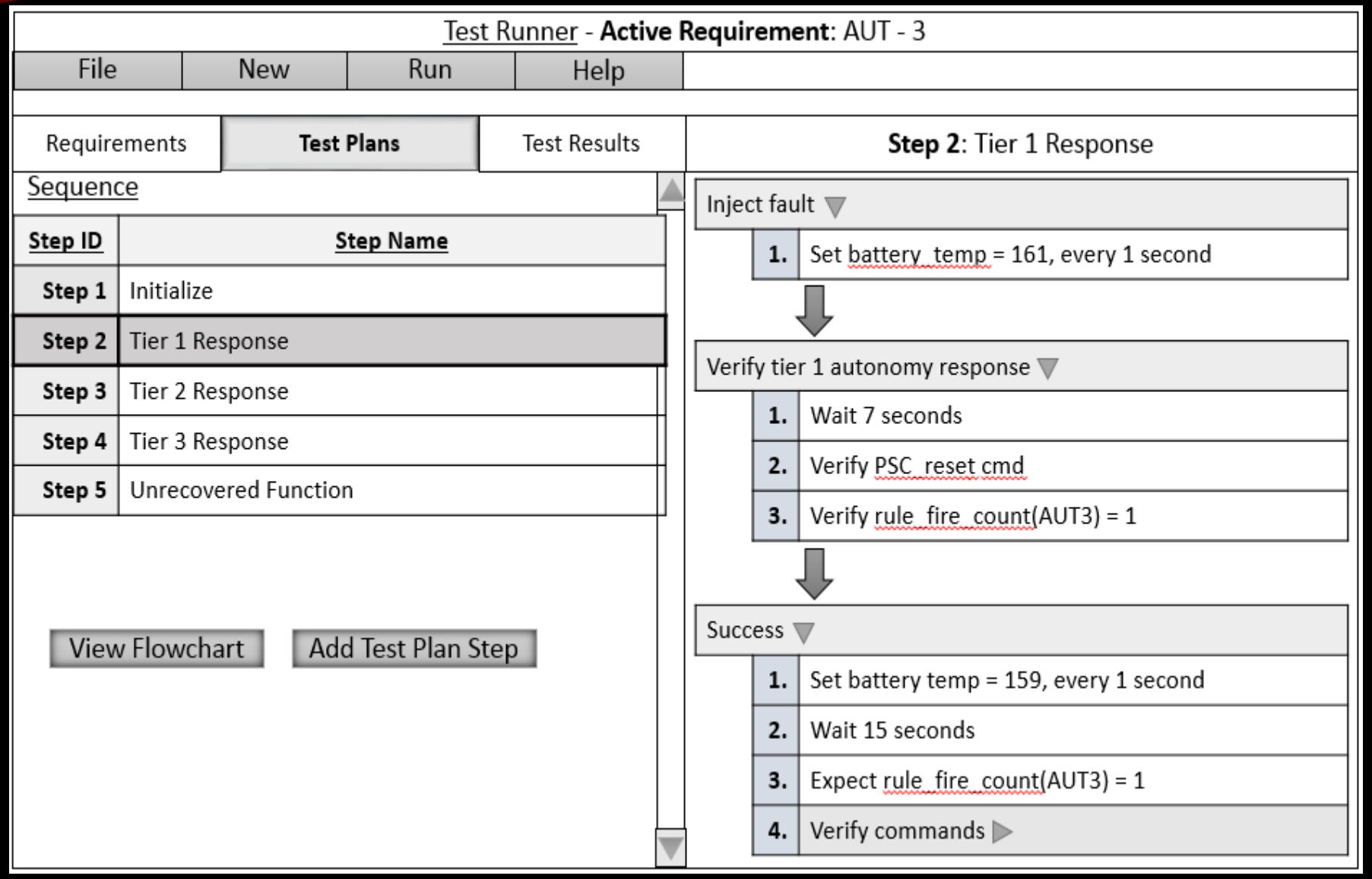
Details

Text	Autonomy shall perform the following tiered response if the battery temperature is above a pre-defined limit: A) Soft-Reset the PSC, B) Power-cycle the PSC, C) Switch the PSC (via a CIM side switch).
Condition	Battery_temp > 160
Subject	Autonomous system
Tiered Action(s)	Soft-reset the PSC, Power-cycle the PSC, Switch the PSC (via a CIM side switch)
Object	PSC
Limit Value	160
Constraint	N/A

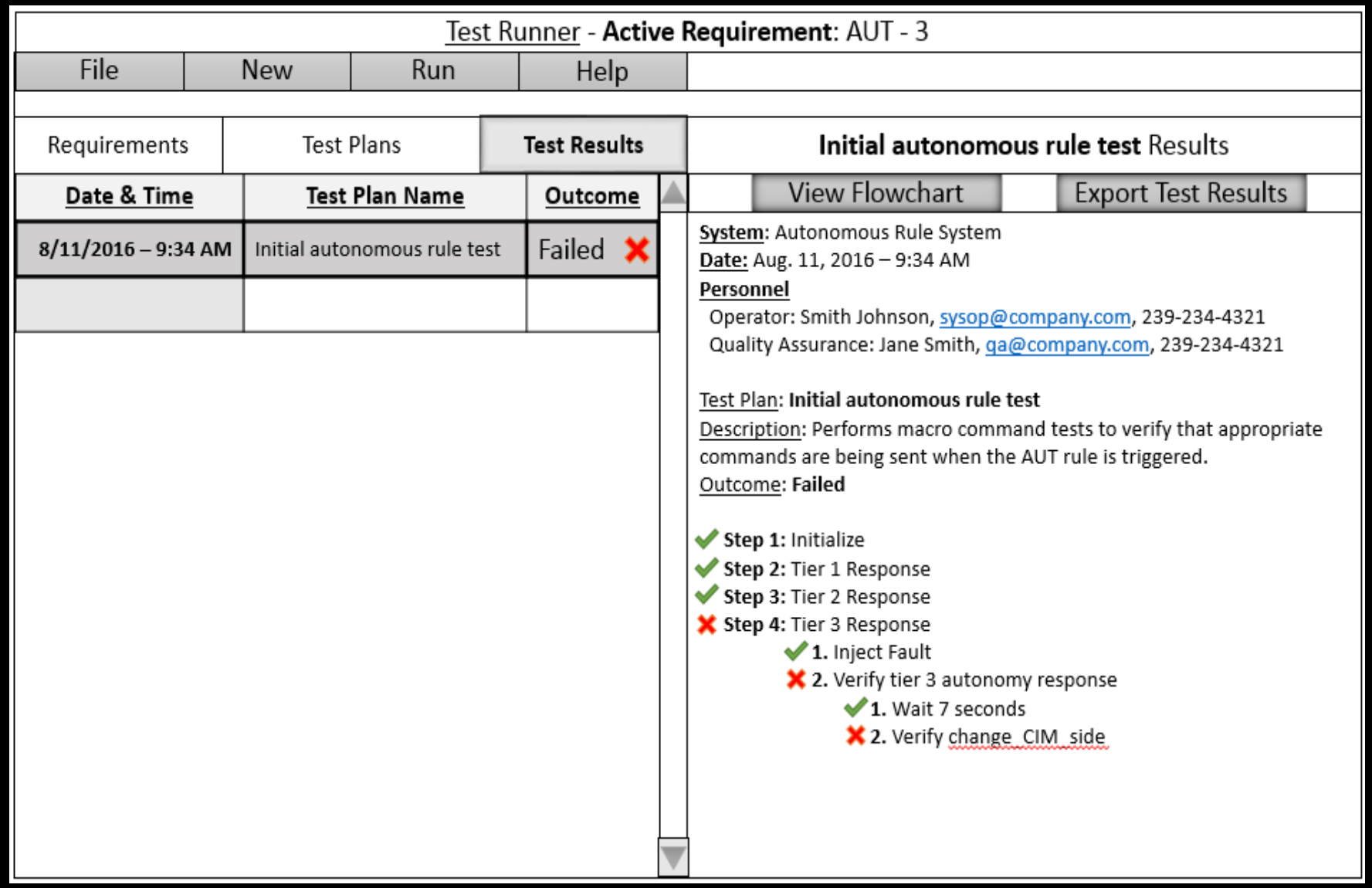
Examples: Test Plan (Flowchart)



Examples: Test Plan (Details)



Examples: Test Results



Advantages of this Method

- Start test driven development early
- Express autonomy requirements in terms of expected behavior
- Support pre-integration testing
- Make integration testing time more productive – no logic errors in software
- During integration, if software changes are required:
  - Make the changes
  - Re-run the pre-integration test to ensure no errors were inadvertently entered
  - Resume integration testing

Innovations

- Represent requirements and link with intended behaviors for testing the requirements (Survey issue #1)
- Formal data models for requirements, behavioral expectations, test specifications, and test results (Survey issue #1)
- Use of template to drive the elaboration of test specifications
- Integration of the testing mechanism with the operational environment
  - Enabled by modular architecture w/ pub-sub communications scheme
  - No change to the unit under test between testing and operations
  - Paves the way for runtime checkout routines for selected apps (e.g., sensors for deep-space science operations)
- Reporting of test results – similar appearance to specifications, still linked to requirements (Survey issue #2)

Next Steps

- Complete development of the ART tool and associated user interfaces
- Identify how to support higher levels of integration testing
- Identify how to support additional types of autonomy requirements
- Update overall documentation and documentation for all requirement schemas (formal data models)