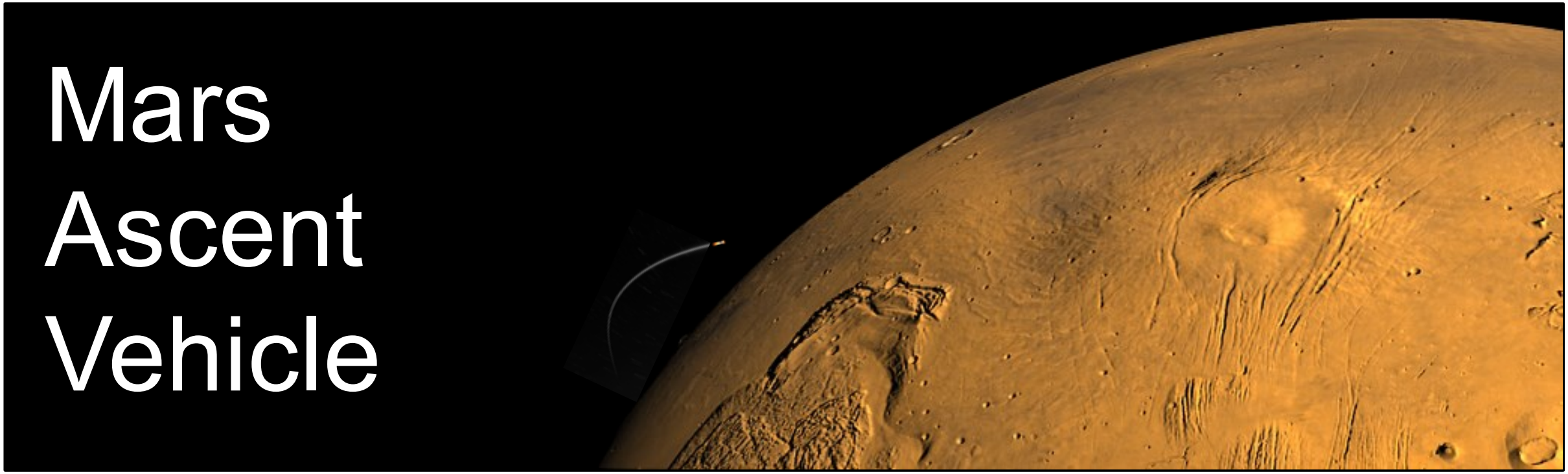
# Mars Ascent Vehicle



Jet Propulsion Laboratory
California Institute of Technology

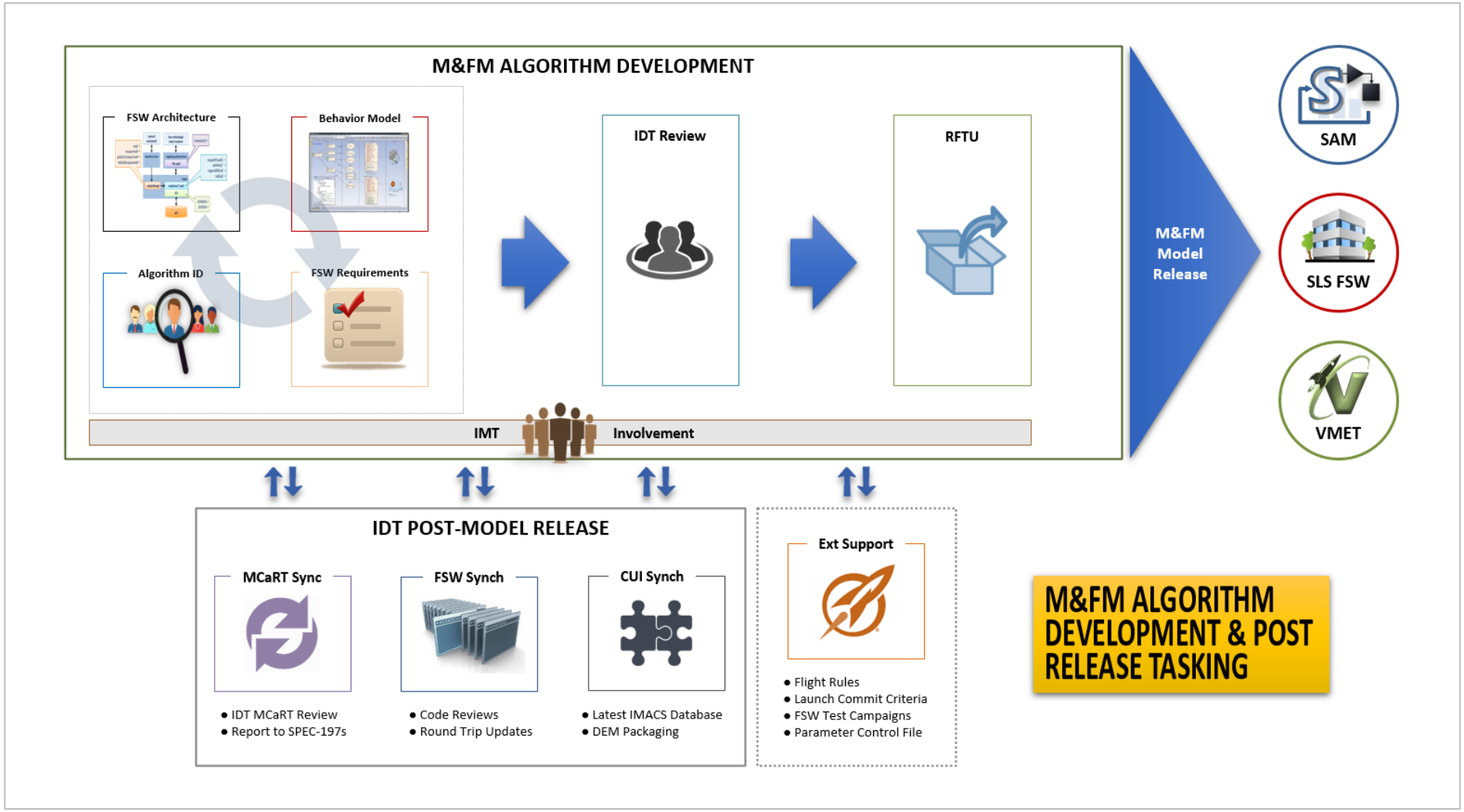
MARSHALL SPACE FLIGHT CENTER

## Emulation of Core Flight System Applications for Flight Software Development and Validation

Cody Wheeler
NASA Marshall Space Flight Center
IEEE Aerospace Conference
10 March 2022

# Mission and Fault Management (EV43)

- NASA MSFC EV43 has extensive experience with algorithm design and test, but less experience with FSW implementation.

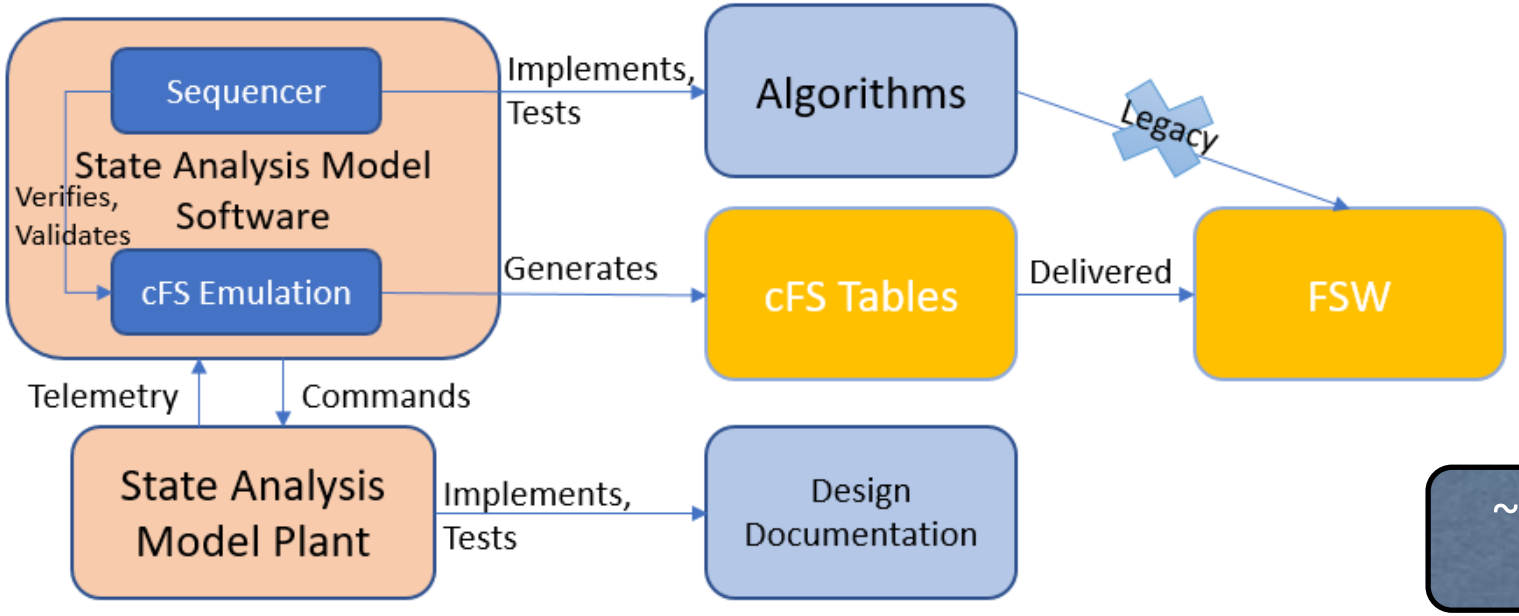


# Tailor the Process to the Purpose



- For a much smaller, drastically less complex vehicle, especially for one without humans, a modified process may be more efficient and effective.

~27k transitions
~12k states

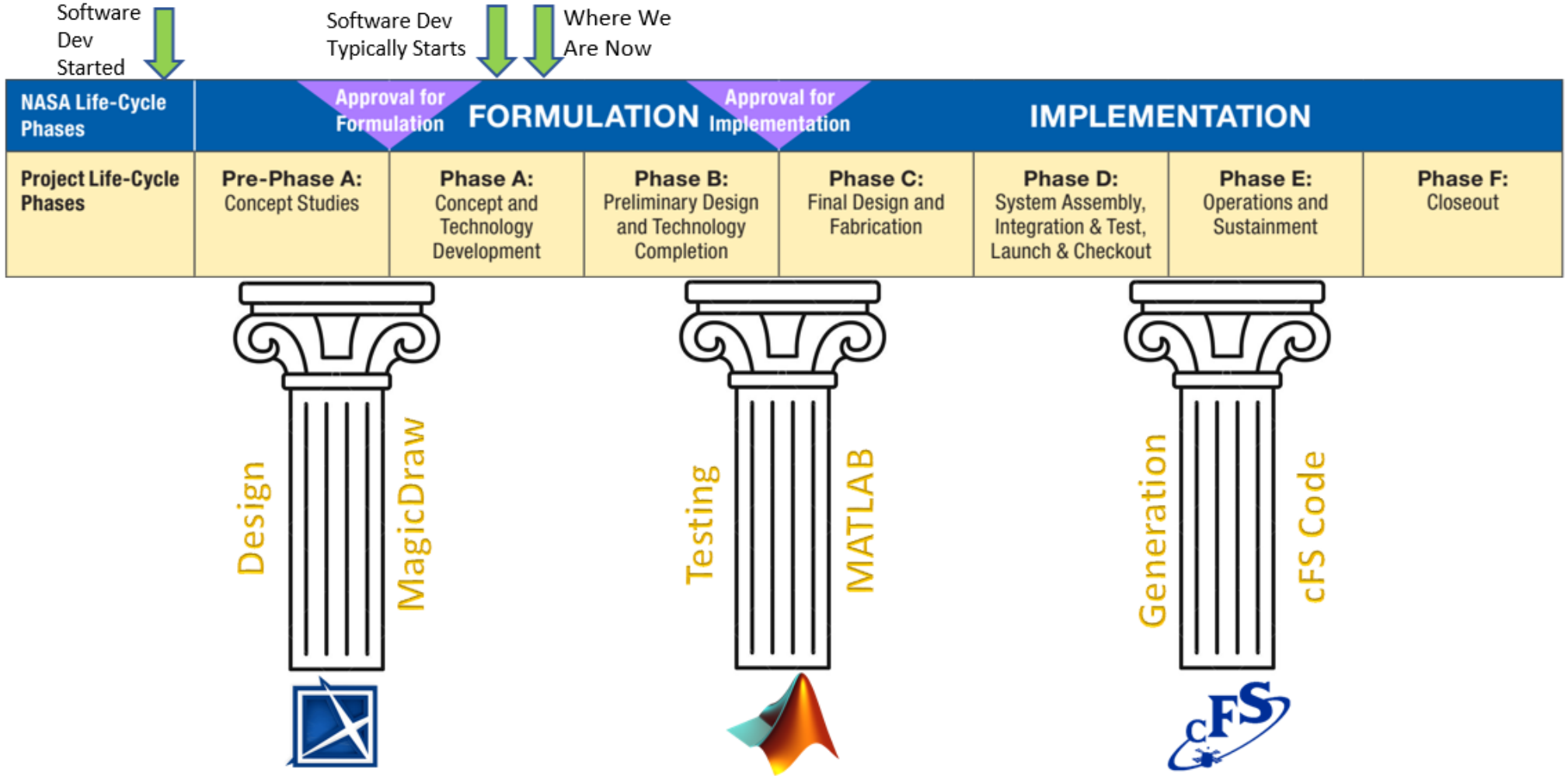



~1000 transitions
~1000 states

# Pillars of Design, Testing, and Generation



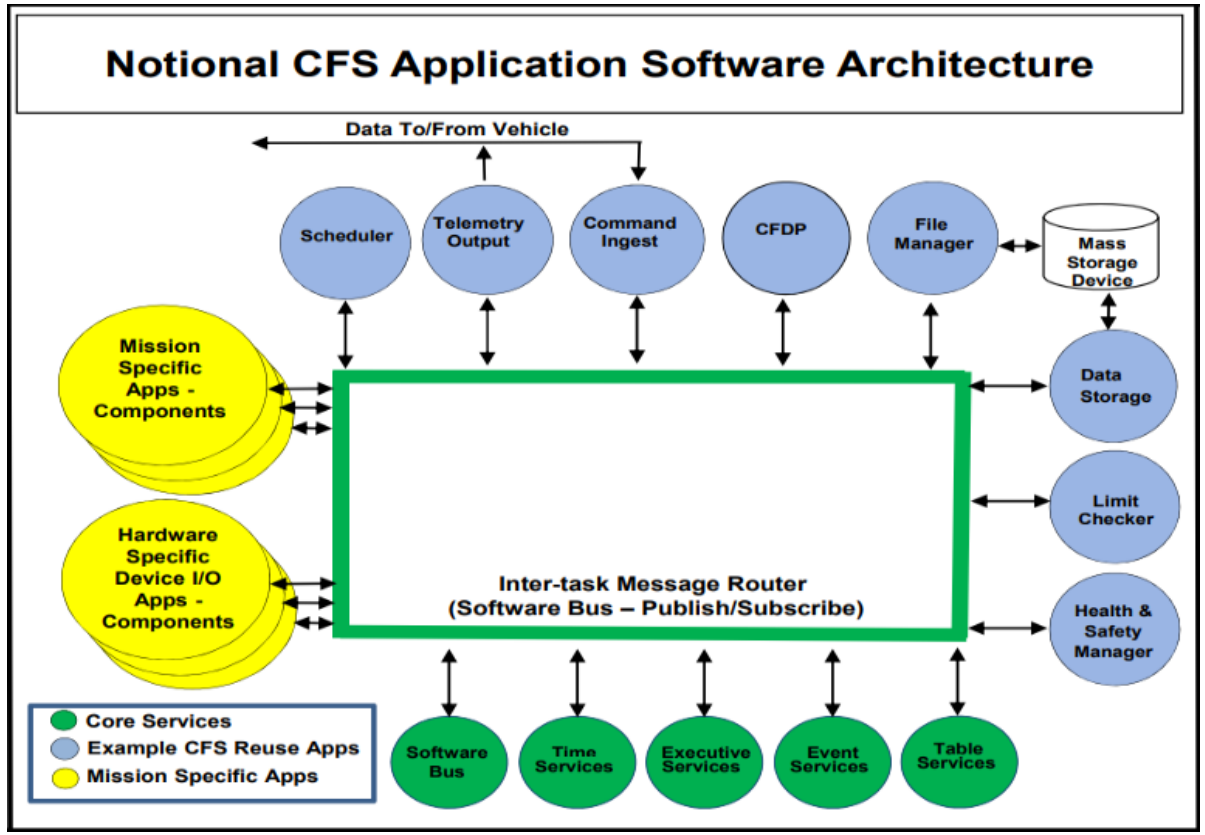
- The process for MAV M&FM has three pillars: algorithm development in MagicDraw, testing and implementation of algorithms in MATLAB, and generation of executable cFS FSW code.

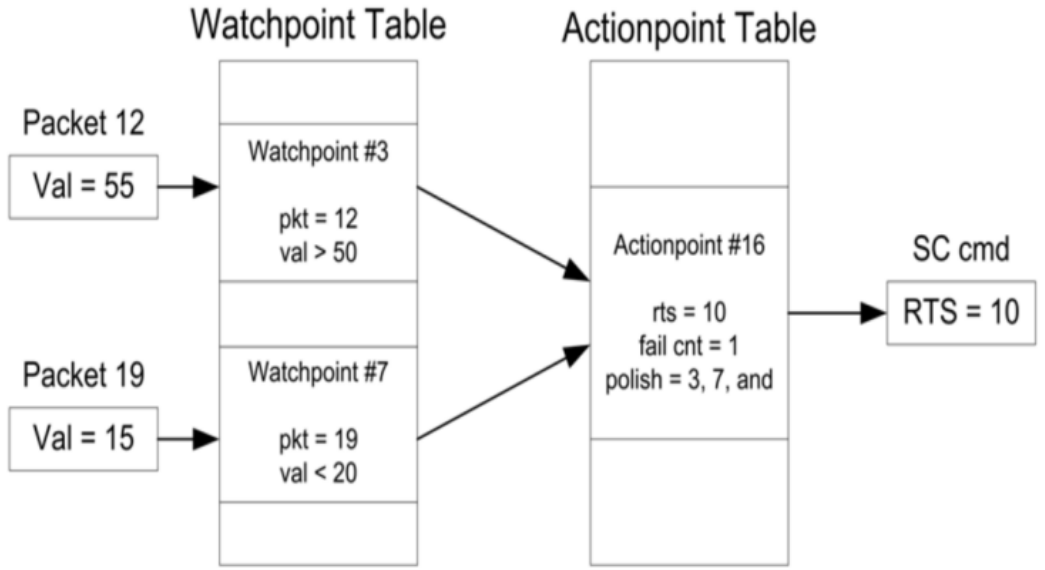


# Core Flight System (cFS)



- Core Flight System is a modular computer architecture that has been used on many space missions. Two key applications that we are interested in are Limit Checker (LC) and Stored Commands (SC). Also, Command Ingest.



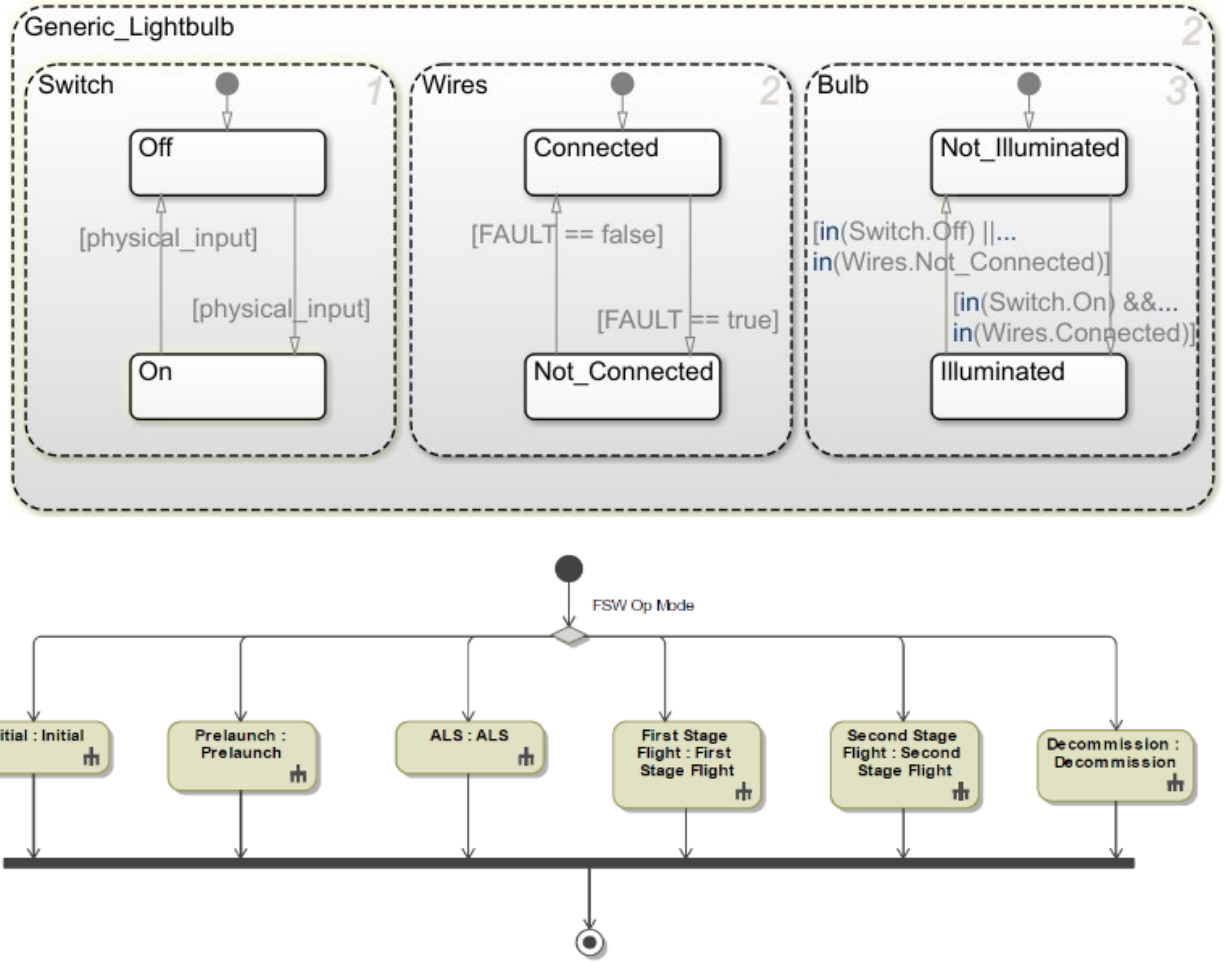




1) Telemetry packet #12 arrives – watchpoint #3 results set to TRUE
2) Telemetry packet #19 arrives – watchpoint #7 results set to TRUE
3) Action command arrives – actionpoint #16 evaluates to FAIL
4) Actionpoint #16 triggers – LC sends command to start RTS #10

# State Analysis Modeling (SAM)

- EV43 leverages in-house modeling and simulation for algorithm testing.

## SAM Plant



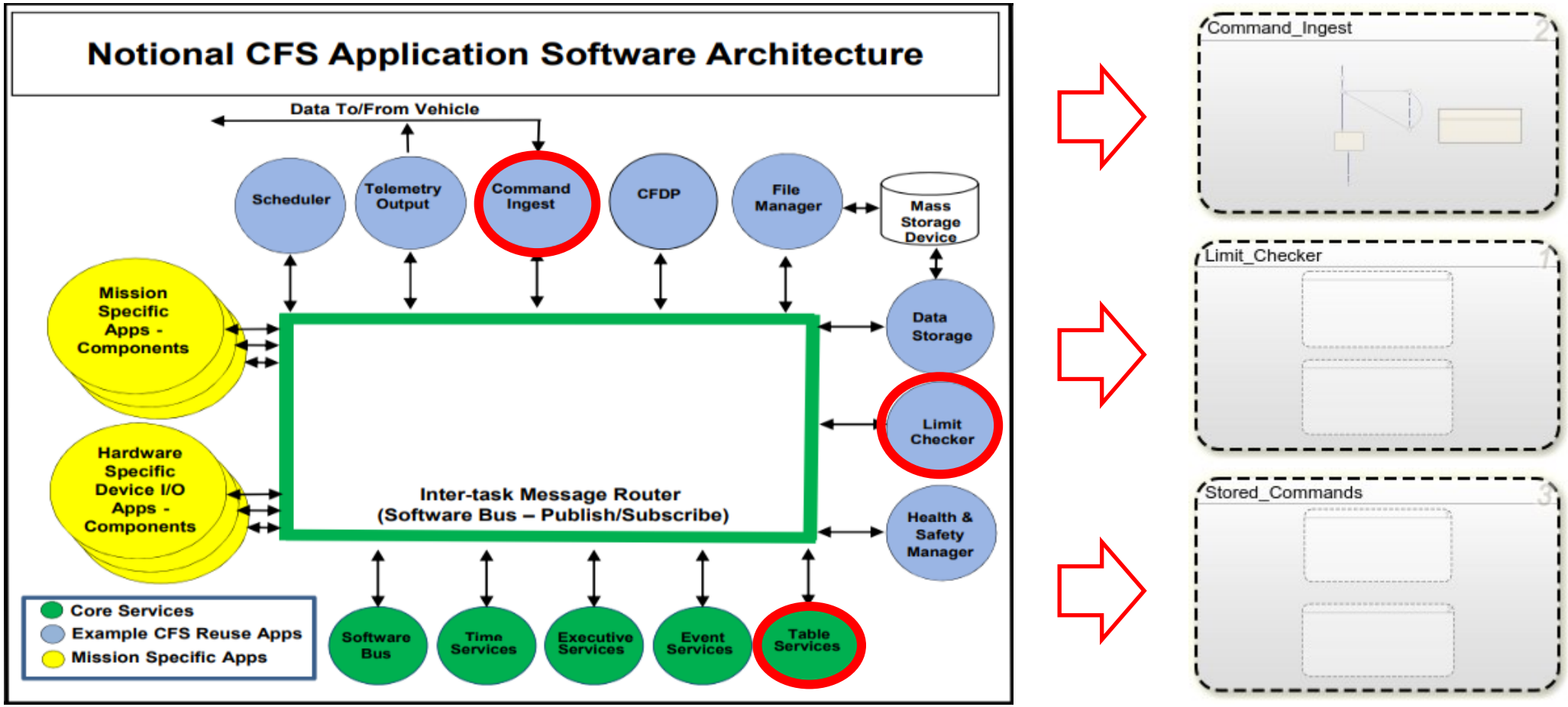

## SAM SW


## SysML Algorithms

# Emulation “Black Box”



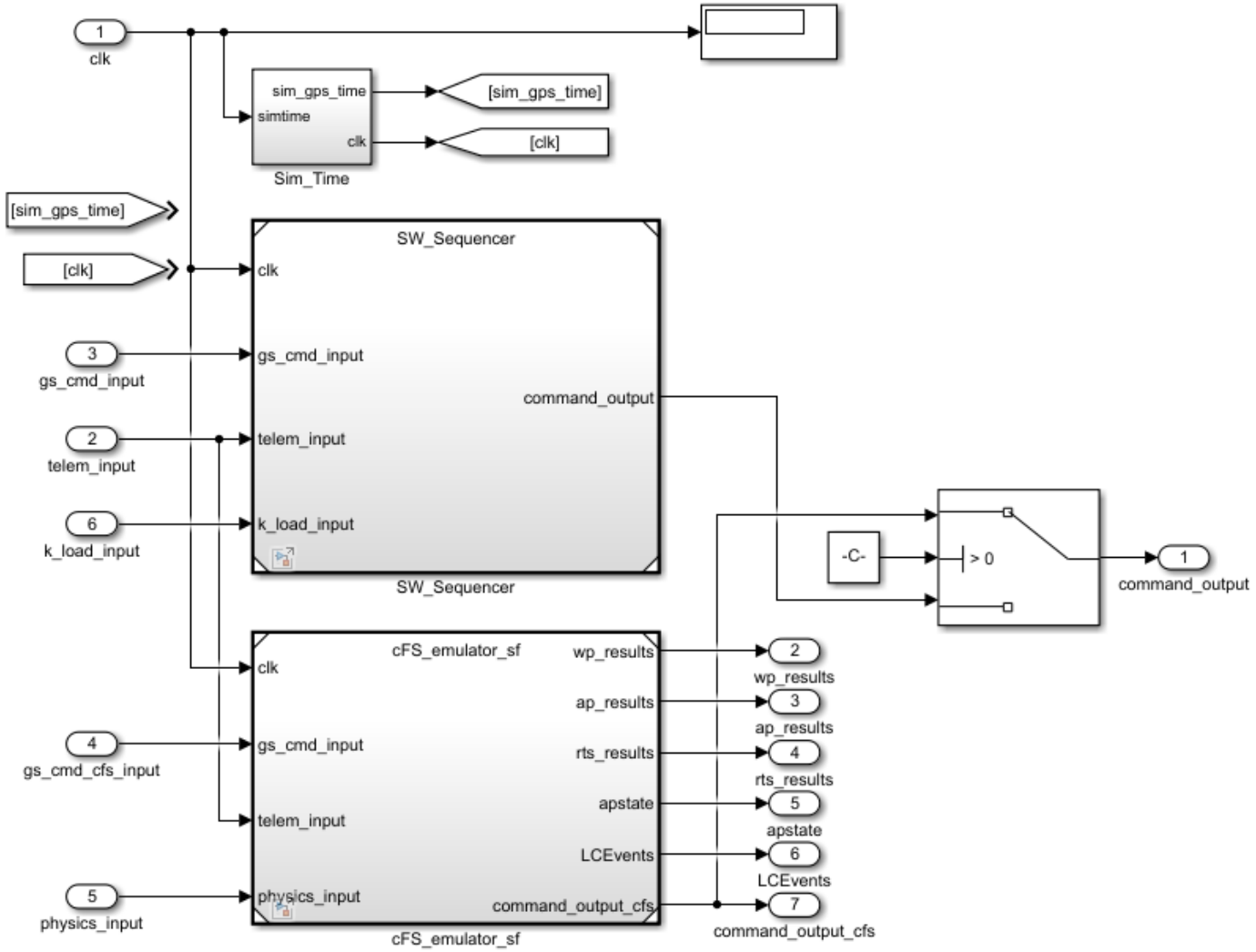
- Basic functions of cFS applications can be emulated in the SAM environment for rapid and accurate results.



# Parallel Execution

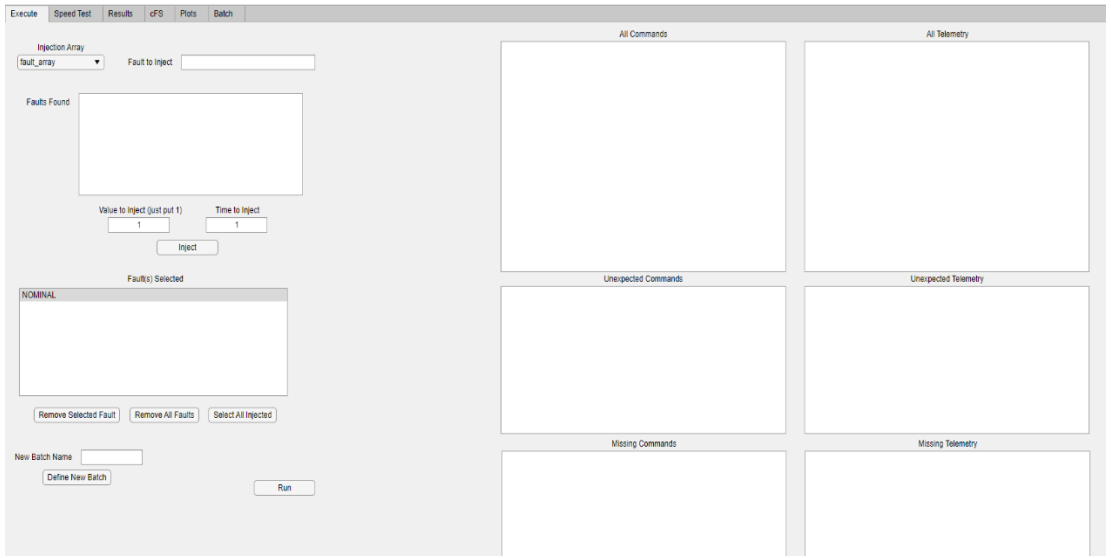


- MATLAB Stateflow Plant and Sequencer Simulation can be run in parallel with cFS emulation.

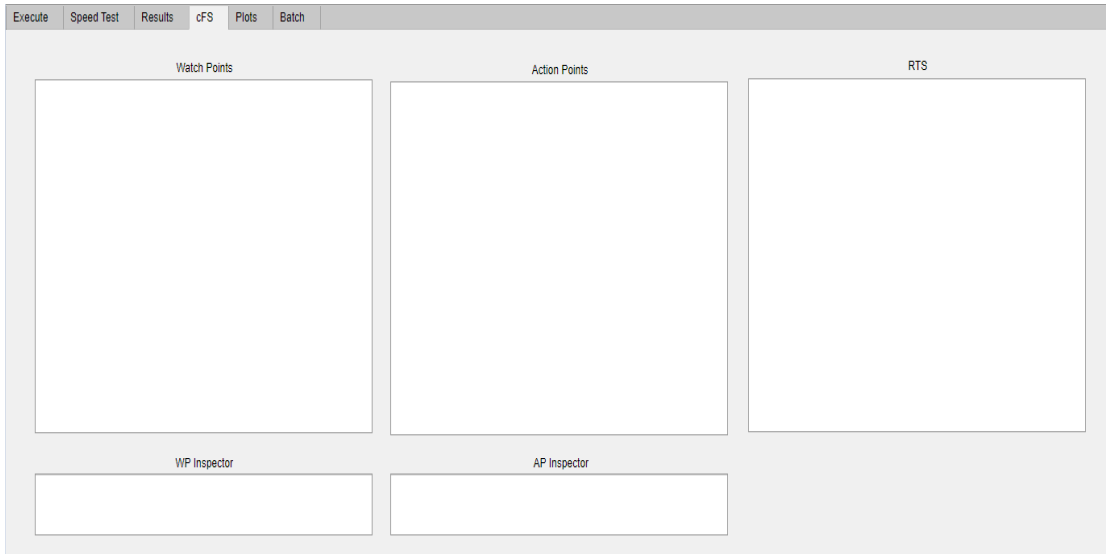


# Simulation and Analysis

- Graphical User Interfaces can be used to compare non-cFS emulation and cFS emulation results.




**Sequencer Results Panes**

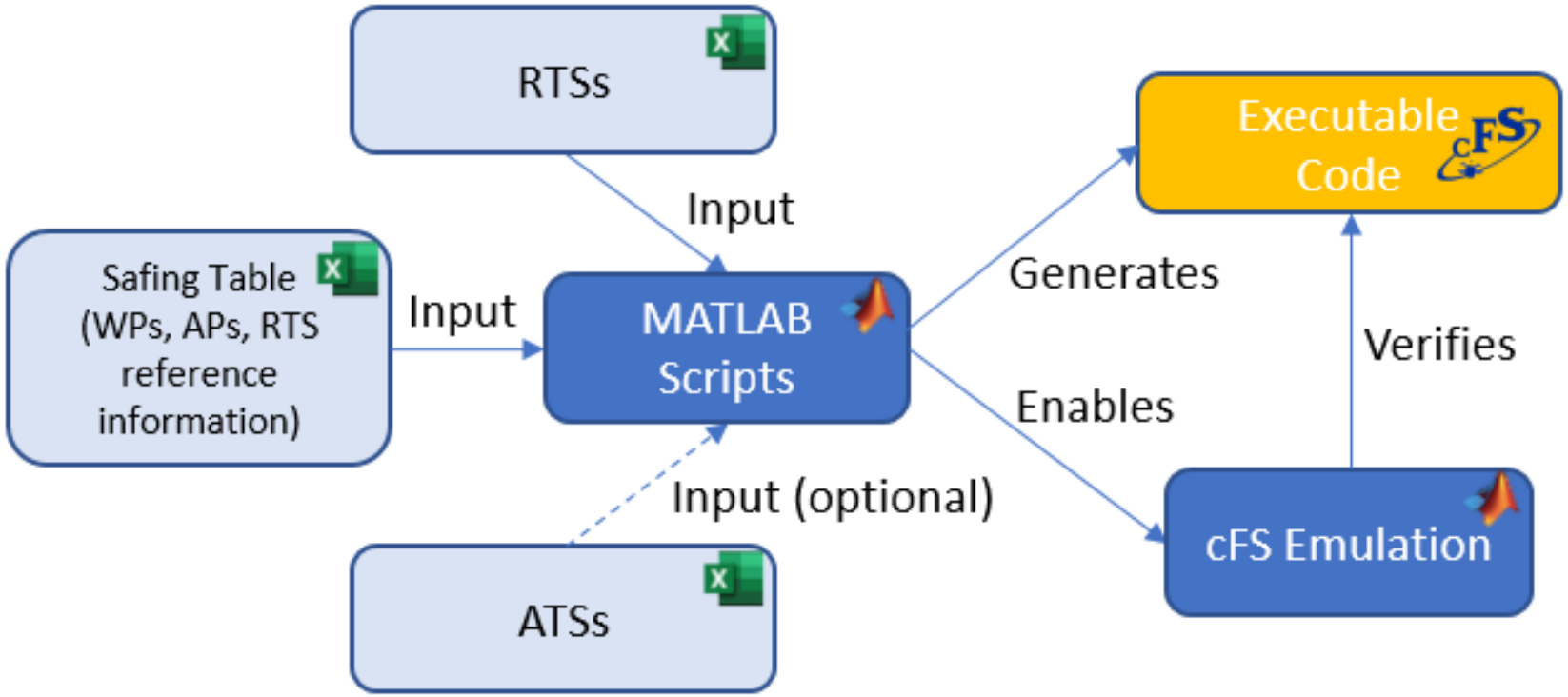



**cFS Emulation Results Panes**

# Table Development and Generation



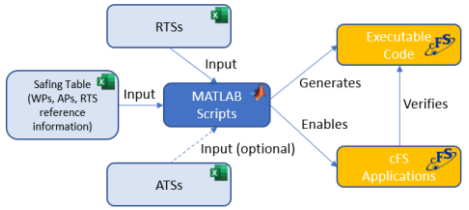
- Excel-based tables can be easy to quickly comprehend and organize, reducing human error. These tables can be run in the SAM for initial verification/validation, then generated into executable cFS FSW code.



# Summary, Forward Work



## Incorporate Full Apps

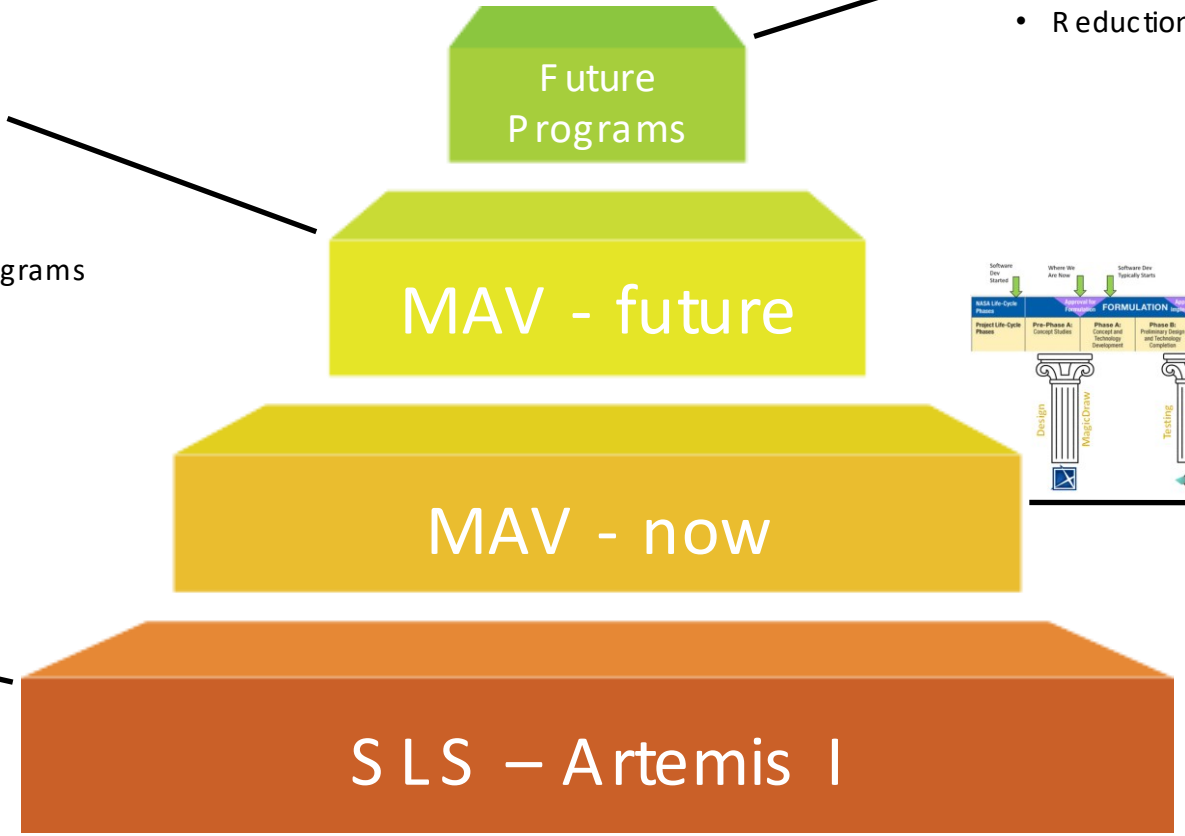


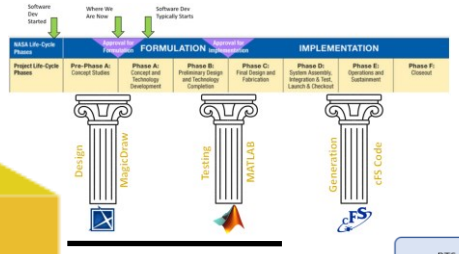

## Increased "Black Box"

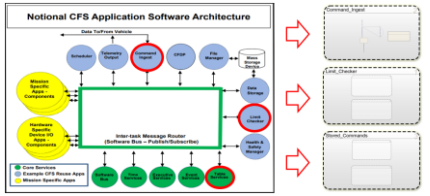

- Earlier and less-expensive M&FM FSW dev
- Reduction in overall FSW dev and testing risks

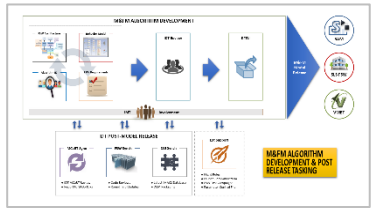
## cFS Table Development in MagicDraw

- Higher-fidelity testing
- Emulation extensible to future programs
- MBSE techniques

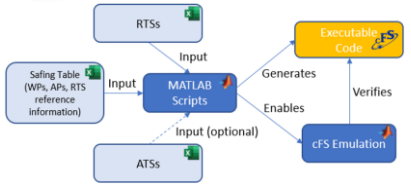


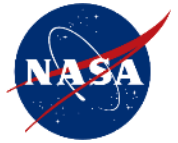

- Large, complex process
- Man-rated missions




- Tailored, refined process
- Development, testing, generation

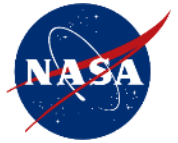
# Backup





# Acknowledgements






- The authors thank the entire MAV team, namely S. Justice and the rest of the MAV FSW team, D. Yaghoubi of the Integrated Analysis team, and S. Maynor.

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# Biography



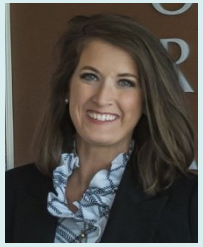

Cody Wheeler


Peter Berg


Mason Ricks


Ashley Jinright


Chandler Millar


Tristan Lane

**Cody Wheeler** is an Aerospace Engineer and has worked at NASA MSFC for 3 years. He has been a member of the MAV team since January 2020. For MAV, Cody is the lead of the State Analysis Team and the lead of the M&FM team. In addition to MAV, Cody also supports the Space Launch System Program on the State Analysis Team and the Human Landing System Program as a Functional Analysis modeler. Cody received a B.S. in Mechanical Engineering from Auburn University in 2018 and a B.S. in Computer Science from Auburn University in 2018.

**Peter P. Berg** is an Aerospace Engineer and the Team Lead of the Integrated Systems Health Management and Automation Branch Analysis Team at NASA MSFC. He served as Flight Software System Engineer, Fault Management Engineer, Simulation Engineer, and as the System Engineer flight controller for LADEE at Ames Research Center. Presently, he works with the Mission and Fault Management Team for the Space Launch System, Human Landing System, Mars Ascent Vehicle, and Solar Cruiser. He is a member of the NASA Engineering and Safety Center's Software Discipline Team where he participated in the Toyota Unintended Acceleration Assessment as well as Commercial Crew Avionics Fault Tolerance Assessment. Peter has received both the NASA Exceptional Public Achievement and NASA Exceptional Engineering Achievement Medals. Peter has a B.S. in Aerospace Engineering from Embry-Riddle Aeronautical University with Minors in both Mathematics and Physics.

**Mason Ricks** received a B.S. in Mechanical Engineering from the University of South Florida in 2019 and started working at NASA MSFC in the Fall of 2019 as contractor support. He has been a member of the MAV team since January 2020 as a Stateflow modeler for TVC and Separation Systems, as well as GUI development. Apart from MAV, he has also supported the Space Launch System on the Vehicle Management End-to-End Testbed (VMET) team as an analyst.

**Ashley Jinright** received a B.S. in Mechanical Engineering from Auburn University in 2014. She has worked at NASA MSFC since spring 2020 and has been a member of the MAV team since December of that year. In addition to MAV, Ashley has also supported the Main Propulsion System team for the Space Launch System as an analyst.

**Chandler Millar** interned on the MAV M&FM team in the summer of 2021, namely providing support to the cFS emulation implementation of the M&FM algorithms. He is pursuing a B.S. in Mechanical Engineering with a minor in Entrepreneurship from the University of Utah.

**Tristan Lane** received a B.S in Mechanical Engineering with an Aerospace concentration from the University of Alabama in Huntsville in 2008. She has worked at NASA MSFC for 15 years, first as a part-time student employee working through a cooperative agreement with UAH throughout her college career, and then as a professional after graduation. She was initially hired by Teledyne Brown Engineering supporting Vehicle Management algorithm development for the Constellation Program, and then after 3 years was hired as a NASA Civil Servant within the same organization. She held the Avionics Lead role for Mission & Fault Management for 8 years, along with the Team Lead role for the branch. Tristan currently is the Manager for the M&FM Branch at MSFC.