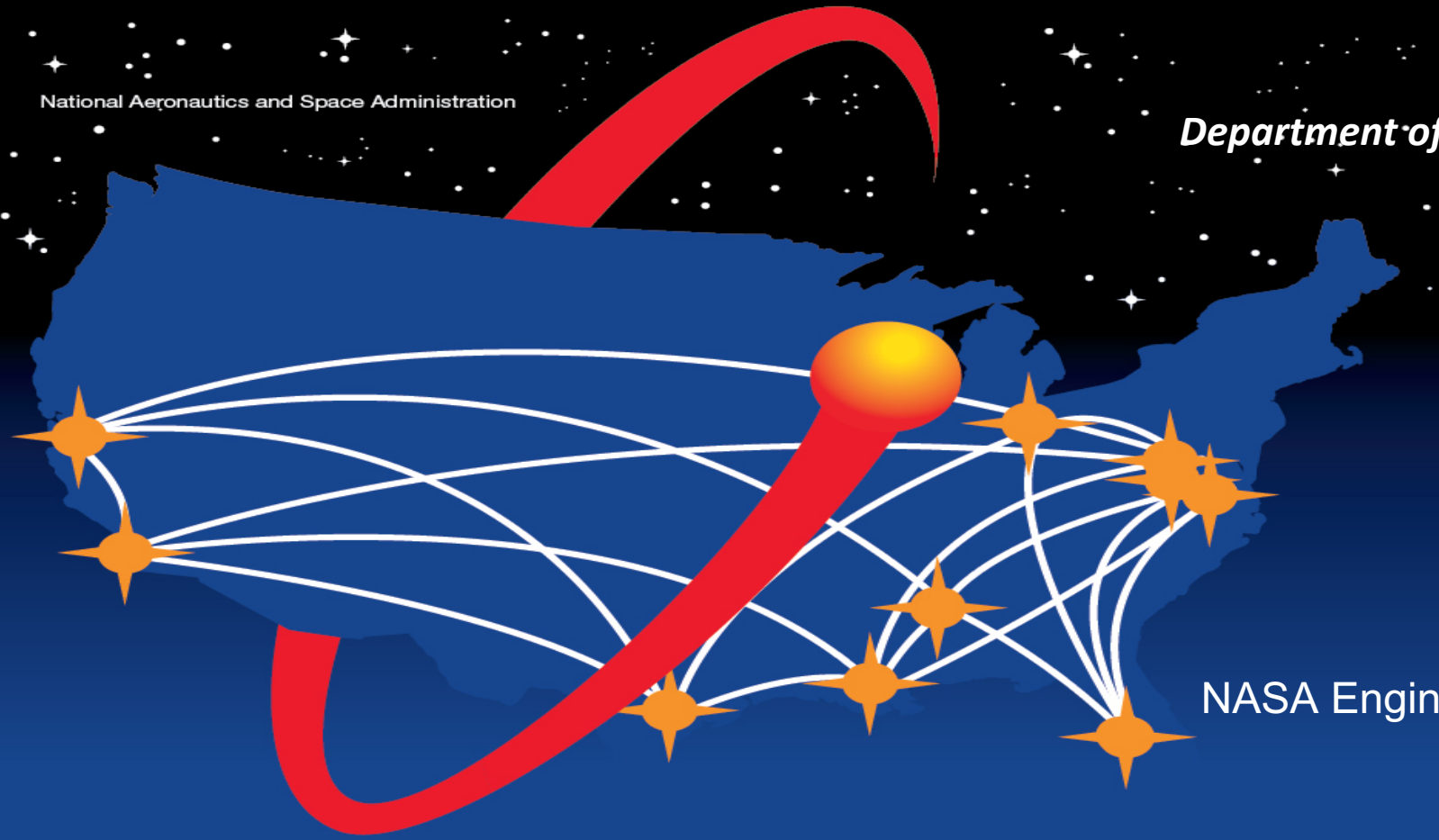
National Aeronautics and Space Administration

Department of Defense NASA Benchmark
June 12, 2020
Virtual Meeting



Jon Holladay
NASA SE Tech Fellow
NASA Engineering and Safety Center

Status to DoD on NASA MBSE Activities

"What we do is important, … and how we do what we do, is just as important."

NASA Systems Engineering
MODEL BASED SYSTEMS ENGINEERING

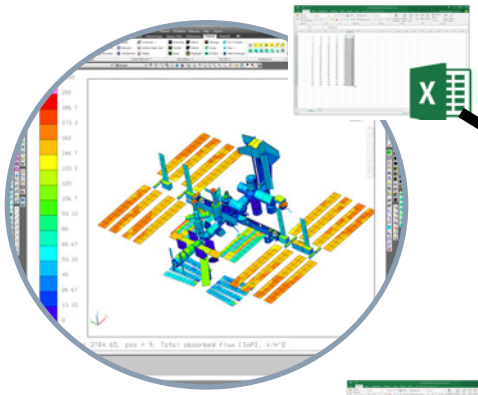
www.nasa.gov

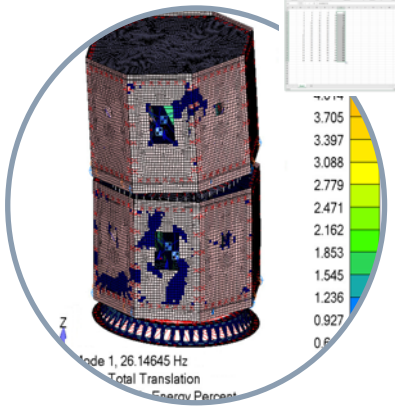
MBSE

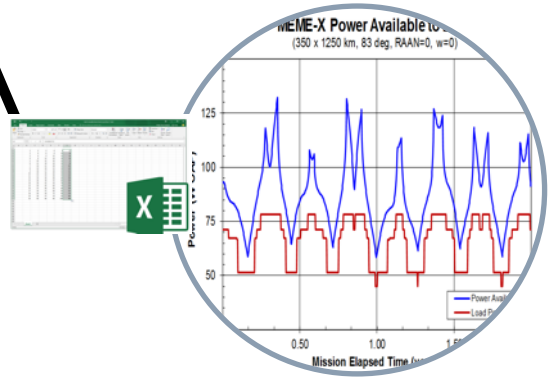
SE&I (Engineering Domain)

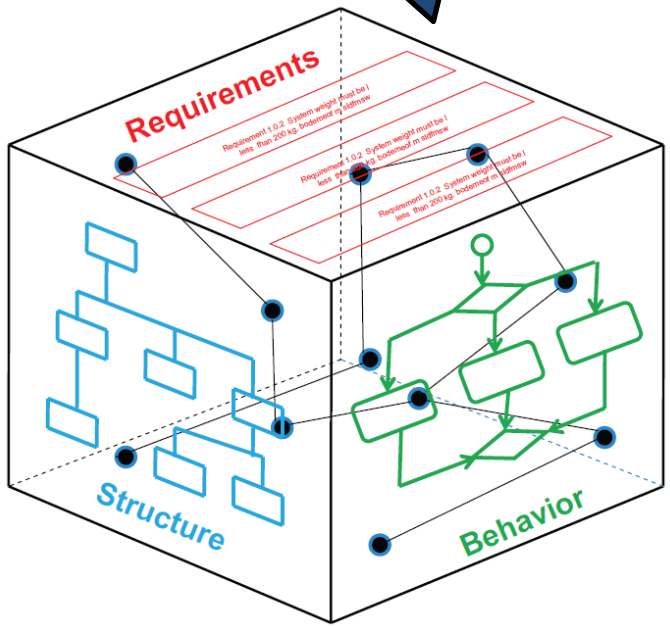
MBSE replaces the description of the system architecture from a disconnected set of documents, with an environment that contains an integrated engineering viewpoint.

$$A = \int f(Excel, Word, Power\ Point) d_{Engineering}$$

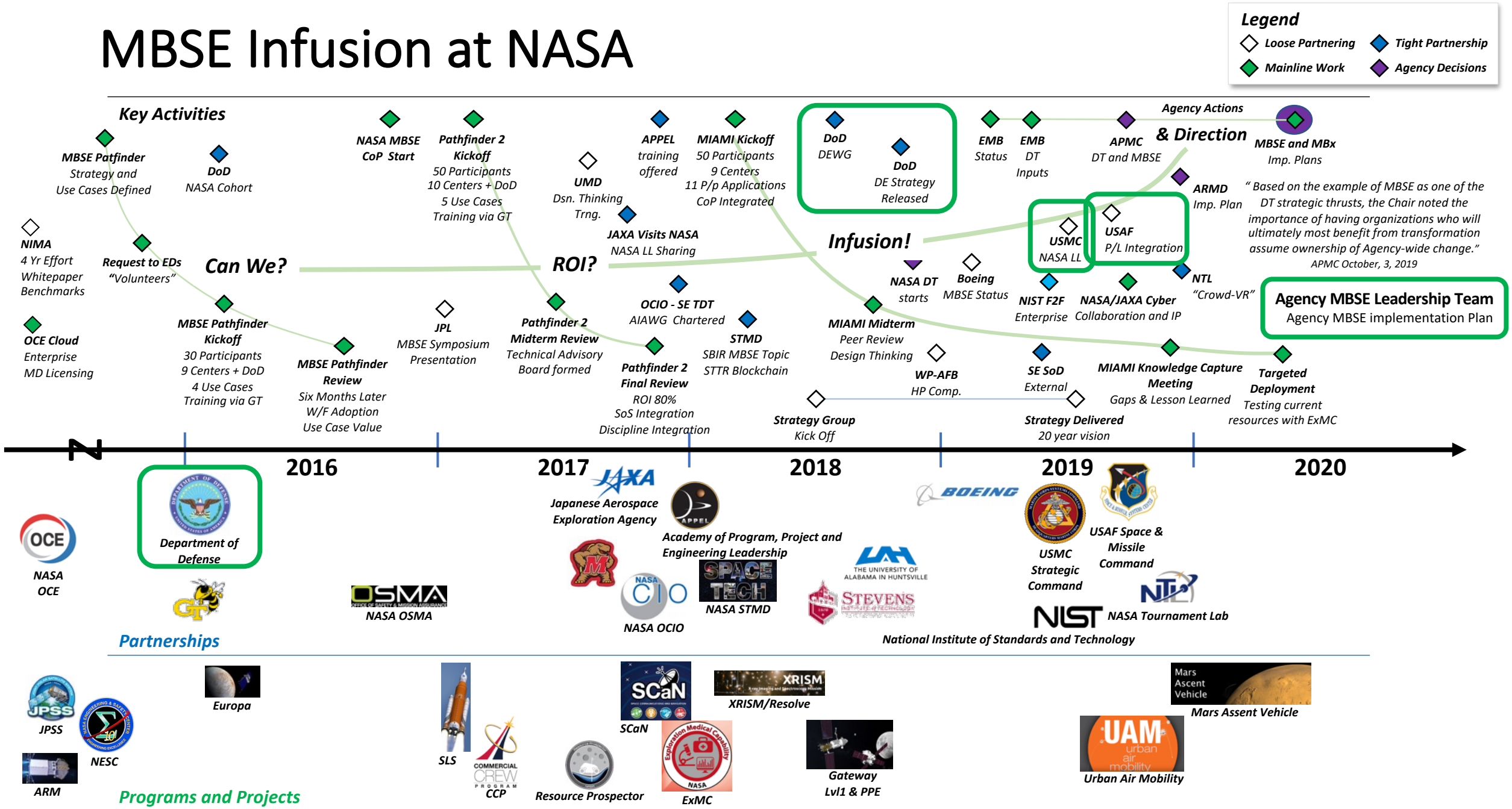








MBSE Infusion at NASA



Demonstrated MBSE Benefits

- **Flexible… data integration and interoperability**
  - Industry standard approach to integration of data
  - Data resides and is maintained by the accountable party, including SE
  - No dedicated army of tailoring and tooling and personnel, COTS implementation
- **Re-use of models … more efficient product generation and knowledge transfer**
  - More rapid start-up and improved efficiency over time
  - Models flow across, and mature with, system life-cycle
  - Validated models offer future opportunity for higher fidelity early life-cycle
- **Models provide "baseline" for other discipline integration**
  - Traditional SE Products (Stakeholder Integration and SE response)
  - More efficient "automation" of trades and tracking of sensitivities
  - Integration of Analytics (CAD, Loads, PRA, FT, Future SE, etc.)
  - Manufacturing (Additive)

MBSE helps focus the art of SE to Engineer the System

Chart content is not standalone, complements verbal presentation.

Global SE State of Discipline Survey

- Information gathered through in-depth **interviews 2019**
- Each report was **developed independently** of one another
- **50 reports from over 56 sources** specified by NASA for contact

Interviews conducted via Harlan Brown and Associates.

OGAs	**10, 20%**
Directors or Department Heads	7, 70%
Systems Development	2, 20%
SE Fellow	1, 10%
Central Office	**4, 40%**
Field/Branch Locations	4, 40%
Pentagon	2, 20%

Tool Vendors	**5, 10%**
MBSE Software	3, 60%
Other Software	2, 40%
Marketing/Sales	**2, 40%**
Chief MBSE Solutions Architect	2, 40%
President	1, 20%
Product Manager	1, 20%

Academia	**12, 24%**
SE/MBSE Researchers	9, 75%
Instructors	8, 67%
Department Chairs	4, 33%
Worked with industry	7, 58%

Industry	**23,46%**
Subcontractors	12, 52%
Consultants	5, 22%
Primes	4, 17%
Suppliers	2, 9%
Space	**11, 48%**
Defense	3, 13%
Space & Defense	9, 39%
Large	**13, 57%**
Small	10, 43%
Domestic (US)	**19, 83%**
International	4, 17%
Division/other level	**18, 78%**
Corporate	5, 22%
Engineer/Practitioner	**12, 52%**
Management	11, 48%

Backup Charts

- Statement on Culture

- What does MBSE&I <u>really</u> look like …

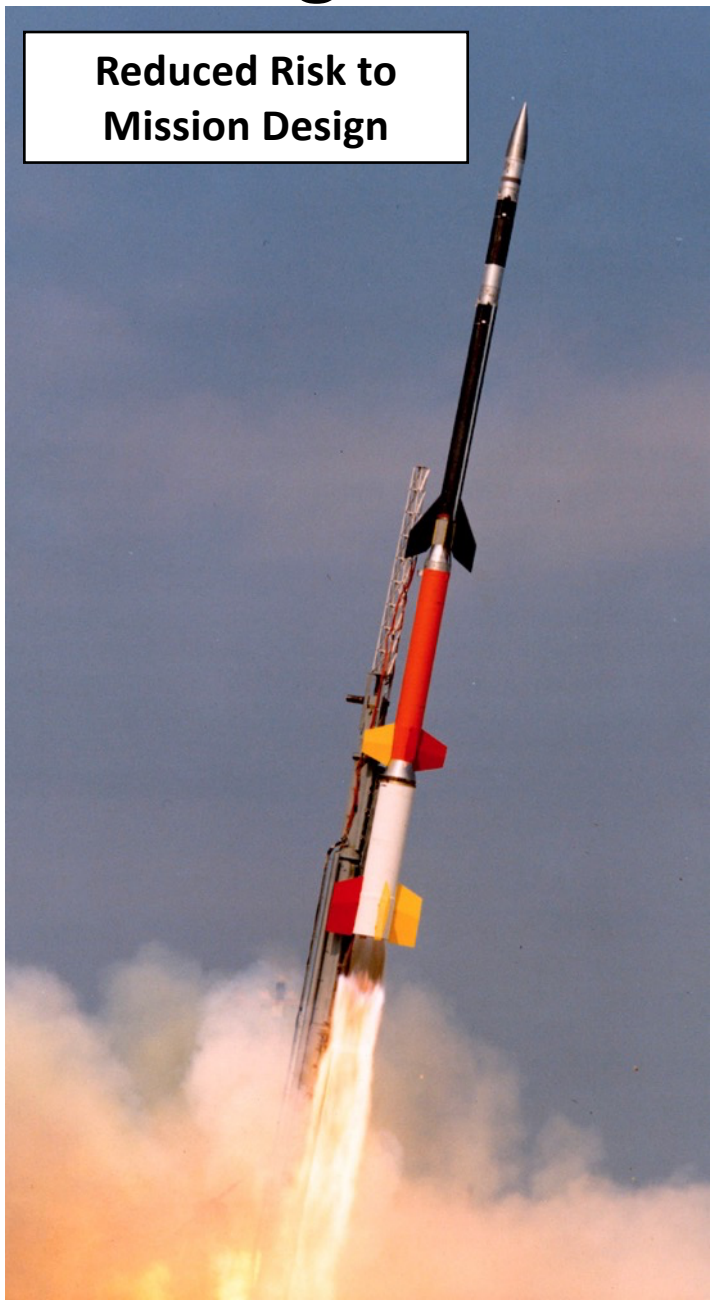
- Mission/Systems Engineering
- Accelerated Design/Manufacture
- Improved V&v and Mode Re-use

- Some References

Don’t Let the Tail Wag the Dog…

Culture Change 101…

Sounding Rocket Automated Vehicle Selection

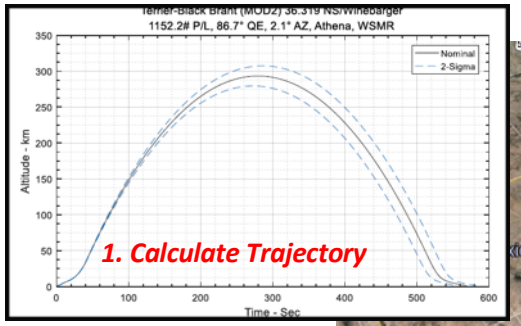


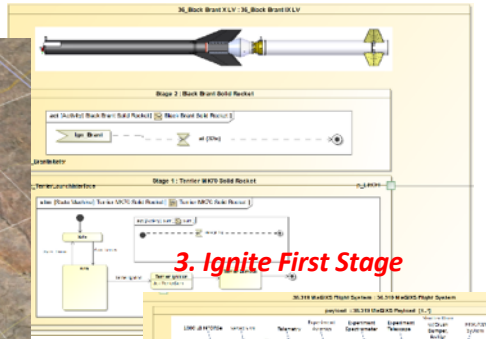
Driver:

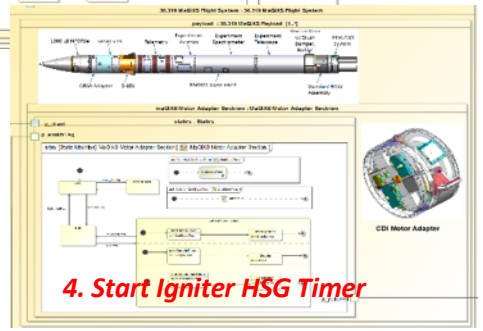
The Sounding Rocket Program would like to ***validate vehicle selection against experimenter needs earlier*** in the project lifecycle in order to reduce design changes later in the lifecycle.

How:

A system model ***links requirements, and potential payload and vehicle configurations*** with a mission feasibility analysis tool to calculate the ***vehicle trajectory,*** inform ***interface definition,*** perform a ***dispersion analysis***, and determine ***margins***.





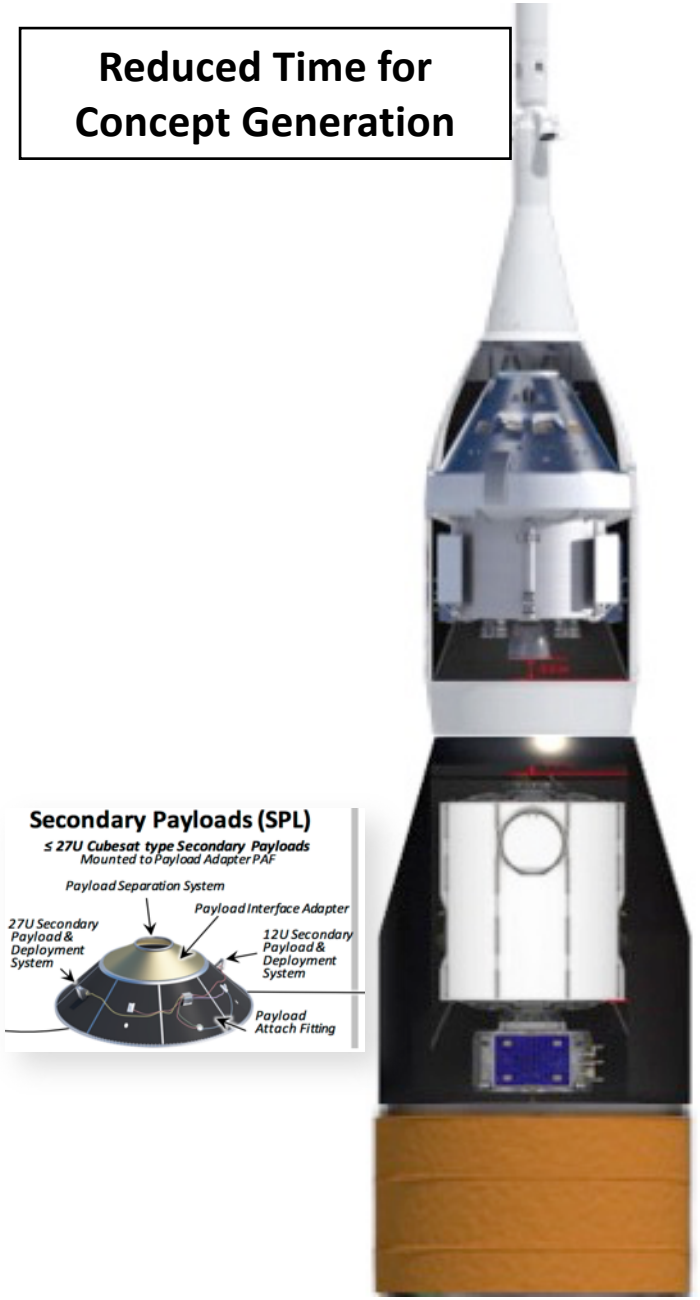


Benefit:

Any vehicle and payload configuration including on sounding rockets, SLS, commercial providers, and partner (eg. DoD, OGA) providers.

Launch Vehicle Payload Adaptor Concept Design

Reduced Time for Concept Generation

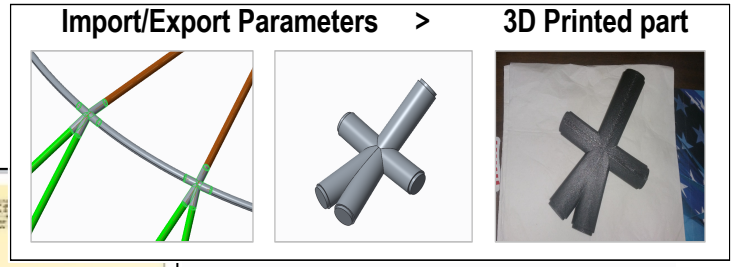


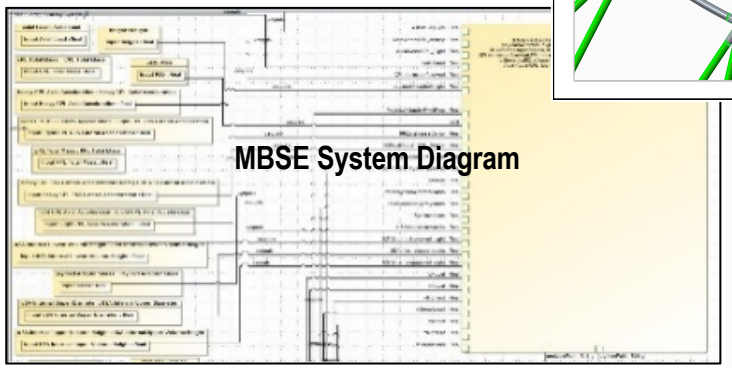
Driver:

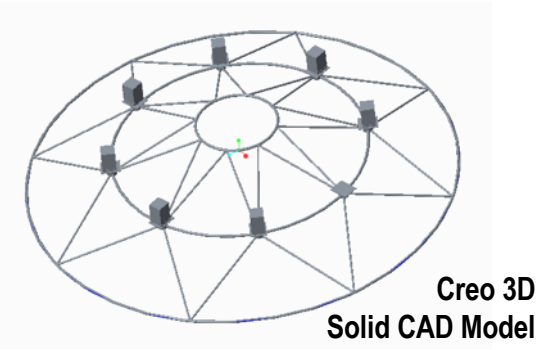
SLS engineering resources are insufficient to ***evaluate 10s-100s of optimized payload adapter options*** for SLS users over life of program.

How:

Linking payload needs with SLS payload adaptor design parameters allows for ***payload adaptor designs to rapidly iterate*** with changing payload needs. New payload adaptor concepts can quickly be ***prototyped via 3D modeling and printing*** technologies.







Benefit:

Any vehicle and payload combination may reuse the ***system model and user interface definition***. *Concept trade space evaluation can also be* ***automated.***

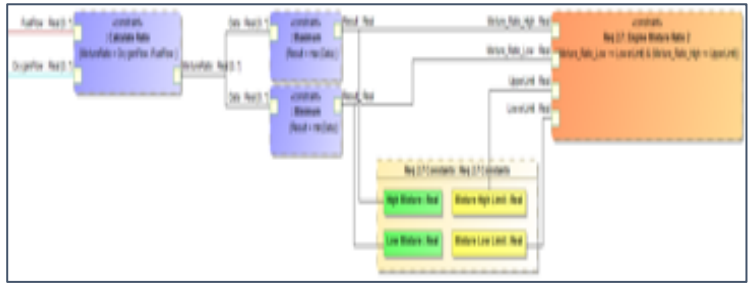
Launch Vehicle Engine Verification and Validation

Driver:

Commercial and NASA engine projects need to ***increase*** engine qualification testing data post-processing ***efficiency and efficacy***.

How:

Linking requirements in a system model with test data for the J-2X engine allows a script to ***automatically verify requirements***. Requirements verification time reduces from 7-9 hours per test to ***1 hour per test***.



#	Name	Start Time : Real	End Time : Real	File Name : String	Req 2.1 Contants : Req 2.1 Constants	Req 2.1 : SL Thrust	Req 2.7 Constants : Req 2.7 Constants	Req 2.7 : Engine Mixture Ratio 2	Req 2.8 : 2.8_SL ISP	Req 4.1 : Req 4.1 Turbin Inlet Temp
1	Test 1	100.0	300.0	a1j026.parms.fixed_rate_50_START.sun	Test 1.req 2.1 C...	fail	Test 1.req 2.7 Co...	pass	fail	pass
2	Test 2	10.0	300.0	a1j025.subset.fixedrate.sun	Test 2.req 2.1 C...	fail	Test 2.req 2.7 Co...	pass	fail	pass
3	Test 3	10.0	300.0	a1j027.subset.fixedrate.sun	Test 3.req 2.1 C...	pass	Test 3.req 2.7 Co...	pass	fail	pass
4	Test 4	10.0	300.0	a1j028.subset.fixedrate.sun	Test 4.req 2.1 C...	fail	Test 4.req 2.7 Co...	fail	fail	pass

Verification Parameters

Requirement Verification

Benefit:

Any vehicle that uses a Lox-H2, gas generator rocket engine – such as Ariane 5, Falcon 9, Falcon Heavy, Delta IV, Saturn V, Soyuz, Long March 3B, Long March 2F – may reuse the ***system model and verification script***.

MBSE Publications and Presentations

2016

- Weiland, K., "Model-Based Project Management: Project Planning & Control Use of a System Model," Agency PP&C Working Group F2F, February 3, 2016, JPL.
- Moreland, R.; Phojanamongkolkij, N.; Knizhnik, J.; Mills, T.; and Weiland, K., "A Survey of Model-Based Programmatic Systems Methodology at NASA," NASA Cost Symposium, August 25, 2016, GRC.
- Weiland, K. "MBSE Pathfinder Overview for OSMA," for HQ OSMA, November 3, 2016.
- Weiland, K., "Model-Based Systems Engineering Pathfinder," SE TDT F2F, May 11, 2016, MAF.
- Moreland, R. and Weiland, K., "Model-Based Project Management: Project Planning & Control Use of a System Model," SE TDT F2F, May 12, 2016, MAF.
- Weiland, K., "Model-Based Systems Engineering Pathfinder Update," SE TDT WebEx, August 5, 2016.
- Phojanamongkolkij, N., "A Model-Based Systems Methodology Application in Architectures and Mission Campaigns," LaRC Systems Engineering Technical Excellence Council (SETEC), August 17, 2016.
- Weiland, K., "Model-Based Systems Engineering Pathfinder 2016 Summary," EMB ViTS, October 20, 2016.
- Weiland, K., "MBSE Pathfinder Results, Plans for FY'17, and Agency Integration Questions," SE CLT F2F, November 2, 2016, GRC.

2017

- Weiland, K. J. and Holladay, J. B., "Model-Based Systems Engineering Pathfinder: Informing the Next Steps," INCOSE 27th International Symposium, July 17-20, 2017, Adelaide, Australia.
- Holladay, J. and Miller, S. T., "NASA's MBSE Pathfinder and New Community of Practice," NASA/JPL Symposium and Workshop on MBSE, January 25-27, 2017, Pasadena, CA.
- Weiland, K. and Holladay, J. B., "NASA Model-Based Systems Engineering Pathfinder 2016 Summary and Path Forward," INCOSE International Workshop 2017, January 28-31, 2017, Torrance, CA.

2018

- Zusack, S., Guariniello, C., and Delaurentis, D., "Operational dependency analysis of a human mars architecture based on the SODA methodology," 2018 IEEE Aerospace Conference, Big Sky, MT.
- Moreland, R., Evans, J., Knizhnik, J., McGowan, A., and Phojanamongkolkij, N., "*Evolving Project Management and System Engineering thru Digital Transformation*," INCOSE 28th International Symposium, July 7-12, 2018, Washington, DC.
- Knizhnik, J., "NASA Implementation Metrics," DoD Digital Engineering Working Group, June 26, 2018, virtual.
- Holladay, J. B., Weiland, K., and Knizhnik, J. R, "NASA Model-based Systems Engineering Infusion and Modernization Initiative (MIAMI). Bridging the Gap: High Performance Computing as an Enabler of Digital Engineering," September 24-25, 2018, W-P AFB, OH.
- Holladay, J., Weiland, K., and Knizhnik, "Digital Transformation Team MIAMI Brief, July 11, 2018.
- Simpson, K. and Weiland, K., "Growing MBSE into NESC Assessments," SE TDT F2F, April 24, 2018.

2019

- Holladay, J. B., Knizhnik, J., Weiland, K., Stein, A., Sanders, T., and Schwindt, T., "MBSE Infusion and Modernization Initiative (MIAMI): "Hot" Benefits for Real NASA Applications," 2019 IEEE Aerospace Conference, Big Sky, MT.
- Holladay, J., Sanders, T., and Smith, D. A., "Enhanced Feasibility Assessment of Payload Adapters for NASA's Space Launch System," 2019 IEEE Aerospace Conference, Big Sky, MT.
- Waldram, N., Cornford, S., Piette, M., and Plattsmier, G., "Cross Lifecycle Modeling in MBSE," 2019 IEEE Aerospace Conference, Big Sky, MT.
- Hanson, A., Mindock, J., Hailey, M., McGuire, K., Bardina, J., Toscano, B., Winther, S., Rubin, D., Cerro, J., Abdelmelek, M., Rubin, A., and Kockler, M., "A Model-Based Systems Engineering Approach to Exploration Medical System Development," 2019 IEEE Aerospace Conference, Big Sky, MT.
- Knizhnik, J. R., Weiland, K. J., Jones-McDowall, K. M., Grondin, T. G., and Holladay, J. B., "Realized Benefits from the Model-Based Systems Engineering Infusion and Modernization Initiative," 2019 JSASS UKAREN, Nov 6-8, 2019, Tokushima, Japan.
- Holladay, J., "NASA's Model Based Systems Engineering Status," Boeing's Model Based Engineering, Community of Excellence, February 19, 2019, Huntsville, AL.
- Holladay, J,, and Jones-McDowall, K., USMC, 2019.
- Holladay, J., USAF, 2019.
- Holladay J., Weiland, K., Knizhnik, J., and Jones-McDowall, K., "MBSE Vision, Benefit, and Strategy: MIAMI Recommendations to Digital Transformation Study Team," March 7, 2019.
- Holladay, J., "MBSE Status," to EMB ViTS, February 7, 2019, virtual.
- Holladay, J., Weiland, K., Knizhnik, J., Grondin, T., and Jones-McDowall, K., "MBSE… What Next?" EMB F2F, April 17, 2019, KSC.

2020 – In-Process

- Knizhnik, J. R. L., Jones-McDowall, K., Weiland, K. J., Holladay, J. B., and Grondin, T., "An Exploration of Lessons Learned from NASA's MBSE Infusion and Modernization Initiative (MIAMI)," 2020 NIST MBE Summit, Mar 30 – Apr 4, 2020, Gaithersburg, MD.