National Aeronautics and Space Administration

Medtronics and NASA Lessons Learned Sharing

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Workforce Efforts in Model Based Systems Engineering

"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

Content Summary

Charts contain an overview of the exploratory evaluation of NASA workforce ability to adopt and apply MBSE, and those lessons learned.

Three priority requirements:

1. **Workforce access to the tool**
2. **Workforce training to apply the tool**
3. **Workforce practitioner and advisor community**

One priority lesson learned:

Focus and "ownership" of transformation lives with frontline workforce

All content is public available, reference materials included at the end of chart deck.

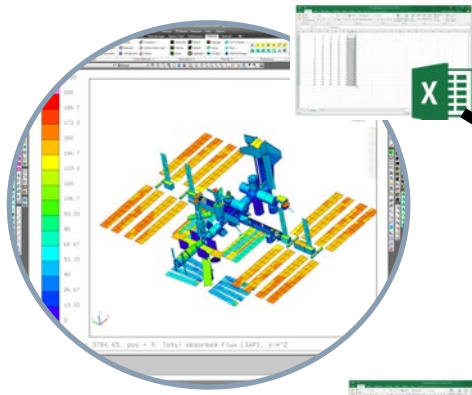
Changing the Culture…

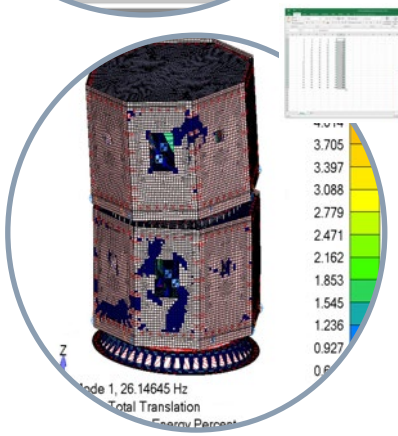
"… we are using up our best people in filling out documentation for their superiors to read, **and most of the time no one is running the store.**"

"SSP has a wealth of data… **without a convenient way to integrate and use the data for management, engineering, or safety decisions."**

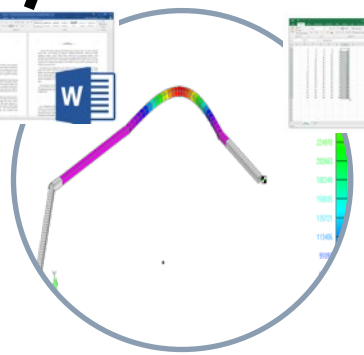
SE&I (Engineering Domain)

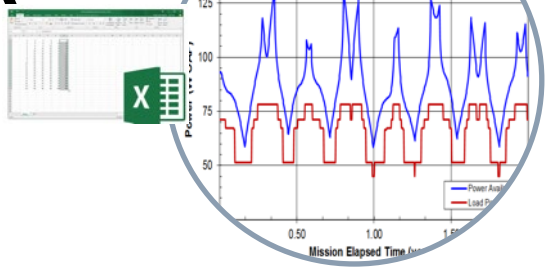
MBSE replaces
the description of the system architecture
from a disconnected set of documents, with an environment
that contains an integrated engineering viewpoint.

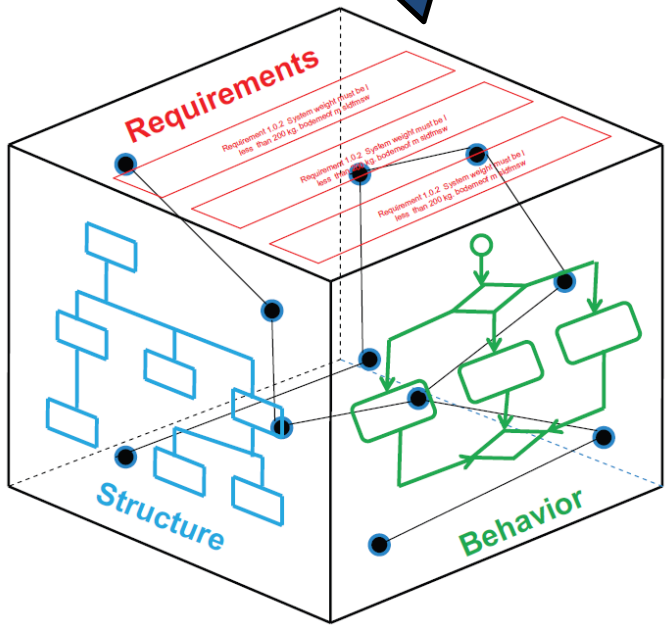




$$A = \int f(Excel, Word, Power\ Point) d_{Engineering}$$







The approach…

LEADERSHIP

Changing Company Culture Requires a Movement, Not a Mandate

by Bryan Walker and Sarah A. Soule

June 20, 2017

Culture is like the wind. It is invisible, yet its effect can be seen and felt. When it is blowing in your direction, it makes for smooth sailing. When it is blowing against you, everything is more difficult.

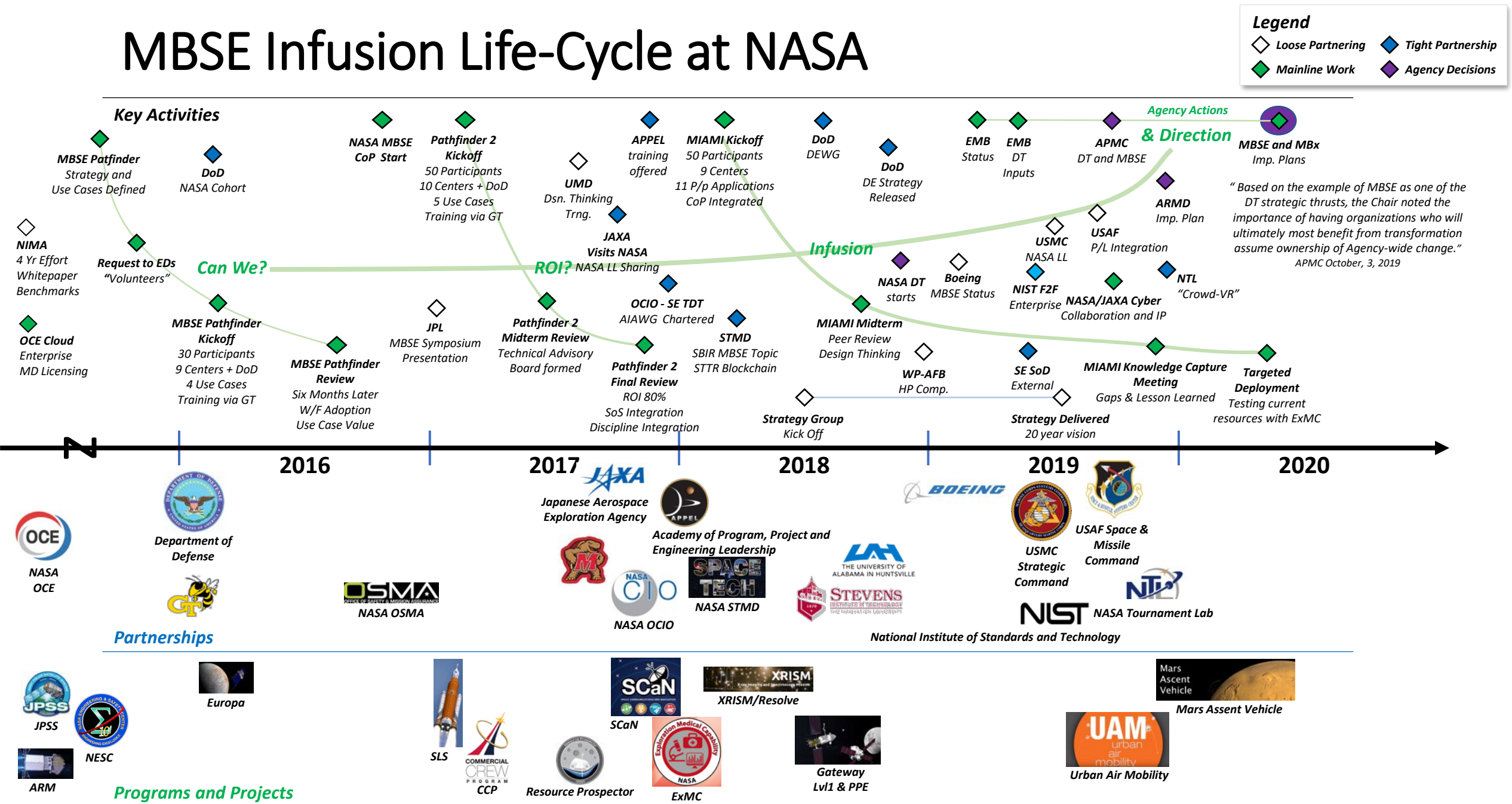
For organizations seeking to become more adaptive and innovative, culture change is often the most challenging part of the transformation. Innovation demands new behaviors from leaders and employees that are often antithetical to corporate cultures, which are historically focused on operational excellence and efficiency.

But culture change can't be achieved through top-down mandate. It lives in the collective hearts and habits of people and their shared perception of "how things are done around here." Someone with authority can demand compliance, but they can't dictate optimism, trust, conviction, or creativity.

https://hbr.org/2017/06/changing-company-culture-requires-a-movement-not-a-mandate

Founder's Mentality: https://www.youtube.com/watch?v=Rp4RCIfX66I

MBSE Infusion Life-Cycle at NASA



FY 16, Can we … ?

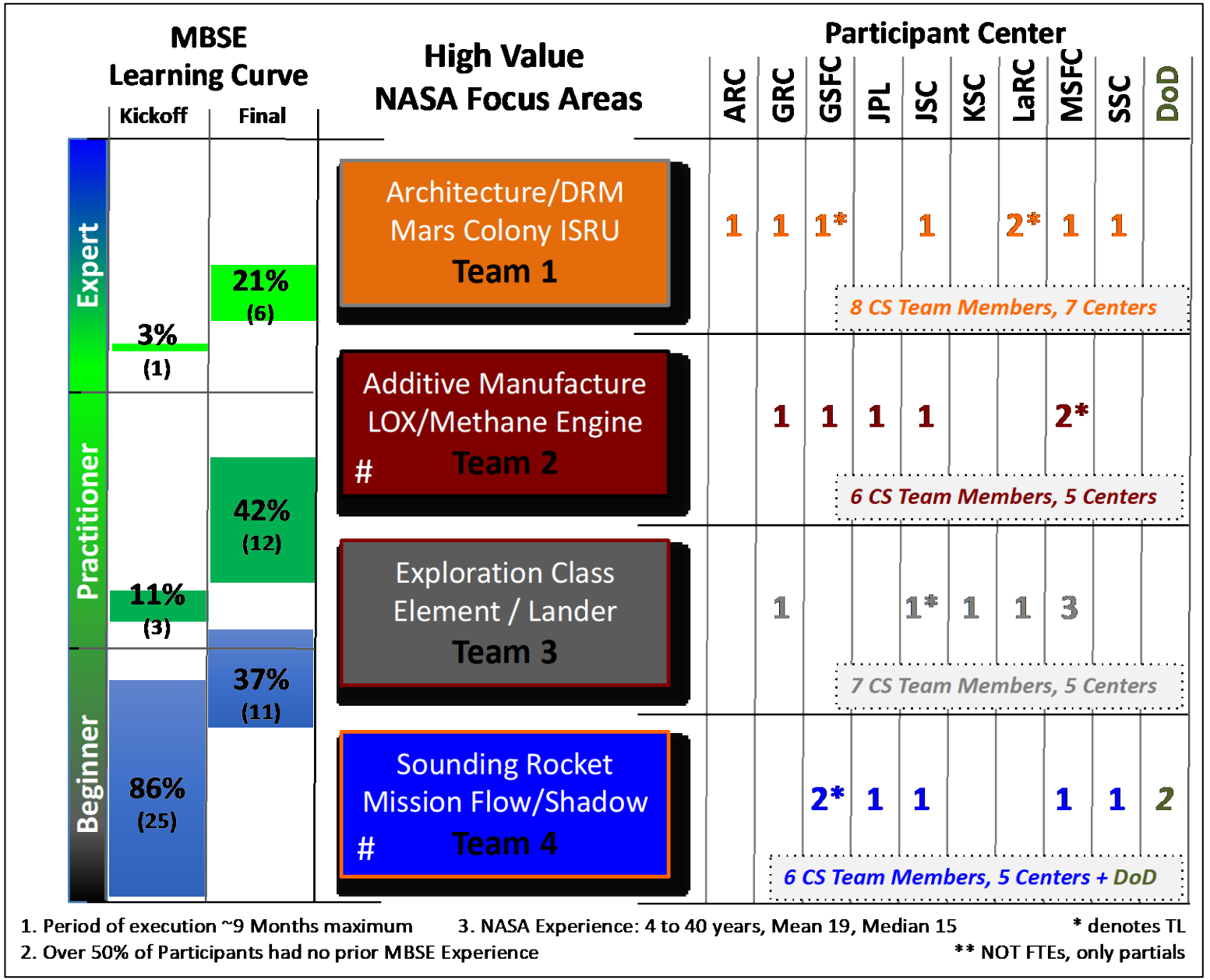
REAL mission use-cases,

- ✓ complicated and complex,
- ✓ highest potential risks…
- ✓ and opportunities ($, t, T).

Six month exercise

- ✓ understand workforce,
- ✓ capability, difficulty, ease…
- ✓ Initial ROI Potential

Poised to intercept upcoming NASA missions and technology selection.

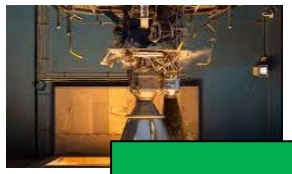


No Cubesats, per Dave Evrett, GSFC!

FY 17, Why should we … ?

LV Engine Additive Mfg.

1. G-G Engine MBSE Patterns
2. Integrated Design Analysis (ROCETS)
3. Concept Trades for Mfg.



Sounding Rocket

1. Full Life-Cycle SE&I
2. Integrated Flight Perf. Analysis
3. Increase Vehicle Selection Confidence

Mars Lander

1. Lander MBSE Patterns
2. S/S Decomposition

Mars ISRU

1. ISRU Factory MBSE Patterns
2. Ingestion of Analysis Data

Model Re-Use

✓ **Model Re-Use**

FY16

FY17

LV Engine V&V

✓ **Time on Task Reduction**

Patterns
omparison)
red

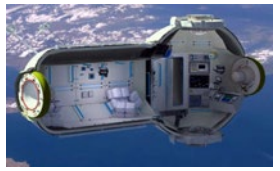
Sounding Rocket

1. Mission Ops Manager Interface
2. Actual Mission Shadow

✓ **Automated Analysis**

"Generic" Space Habitat

1. Re-cycled Lander MBSE Patterns
2. Decomp to ECLSS and Structures
3. ed Concept Gene
4. ed Design Analysis
(CAD, Loads, Mass, etc.)



Mars ISRU

1. Refinement of Analysis

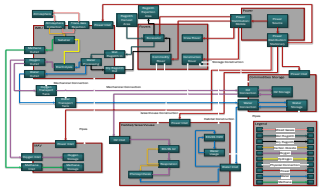
gration

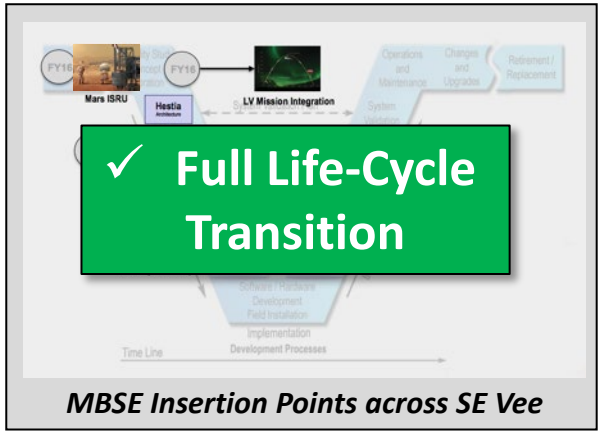
Integration

✓ **System of Systems Integration**

Architecture

1. Full-Up Mars Infrastructure Options
2. Make versus Take Trades
3. Systems Failure Sensitivity



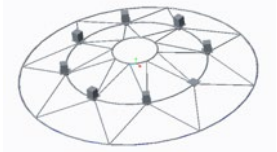


✓ **Full Life-Cycle Transition**

MBSE Insertion Points across SE Vee

LV Payload Adaptor

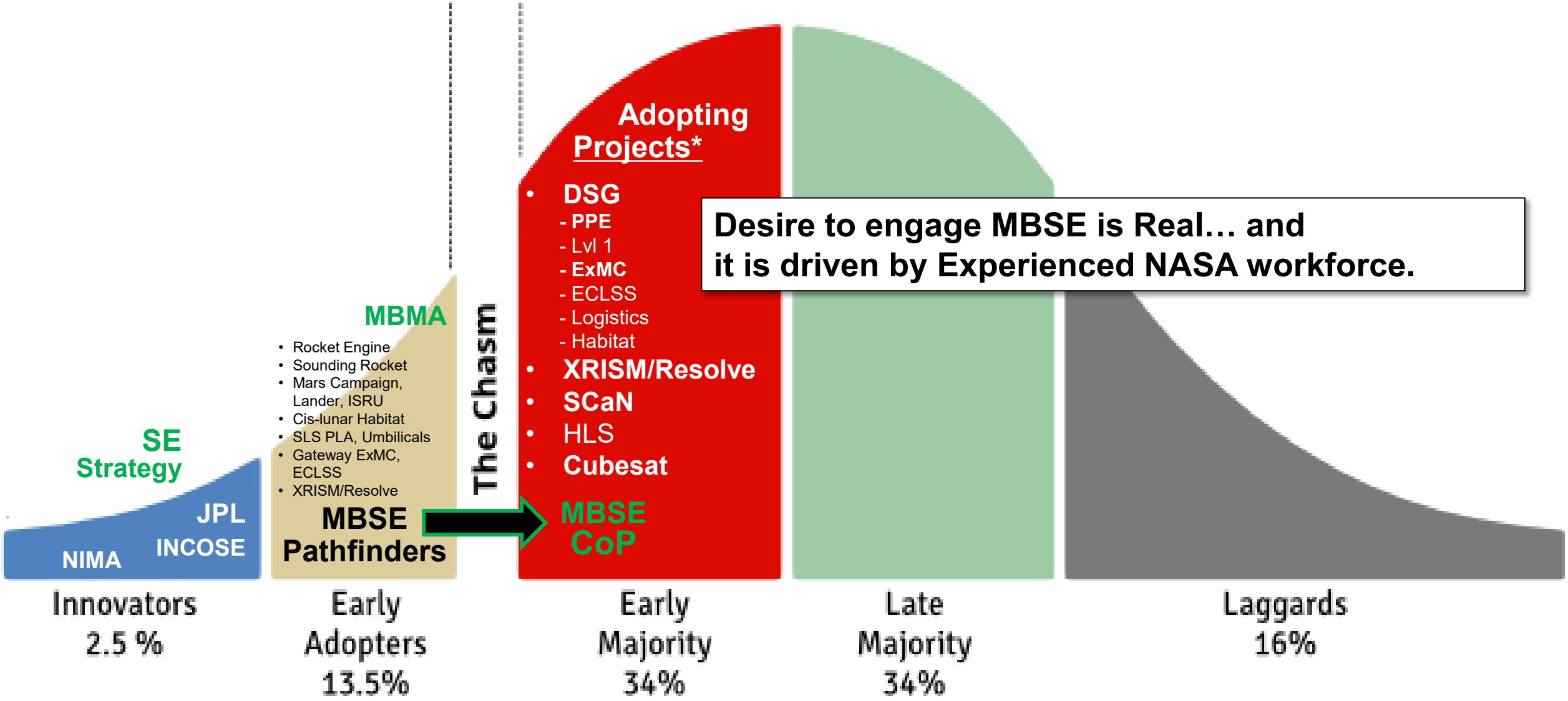
1. Customer Interface
2. Automated Concept Generation
3. Integrated Design Analysis
(CAD, Loads, Mass, etc.)
4. Automated Manufacture Demo
5. SE Product Capture



✓ **Standardized Templates**

Developed to Demo Application, Benefits, and Seed Infusion

FY 18-19, Valley of Death… Moat of Protection



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.

In Summary, what we did?

1. **Understood capability of MBSE … and Workforce**
2. **Legitimately seeded upcoming projects**
3. **Built an INFORMED smart buyer community**
   - ✓ **Hands-on expertise on MBSE… and connection to MBE**
   - ✓ **IT Architecture in which MBSE resides**
   - ✓ **World Class… best in the world.**

Culture Change …

Don't Let the Tail Wag the Dog…

Culture Change 101…

Backup Charts

1. Overview of MBSE, What it Looks Like

- Sounding Rocket
- Payload Adaptor
- Engine V&V

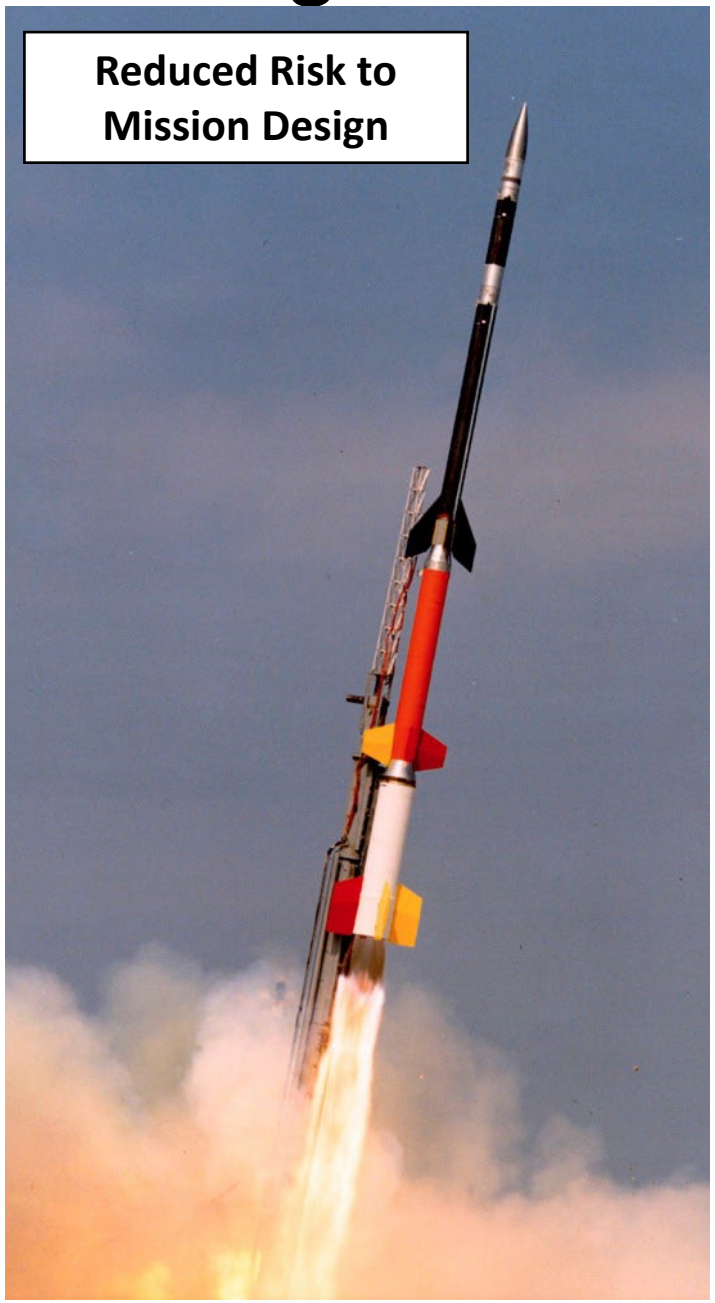
2. MBSE Publications and Presentations

How does MBSE Work?

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

- Sounding Rocket Vehicle Selection
- Launch Vehicle Payload Adaptor(s)
- Launch Vehicle Engine(s)

Sounding Rocket Automated Vehicle Selection

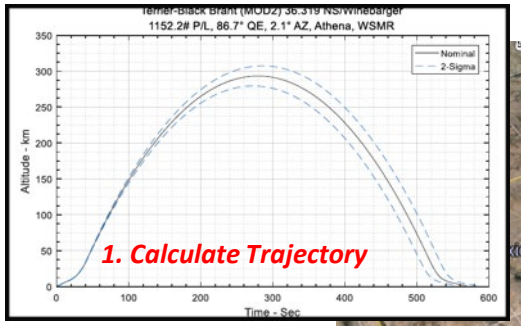


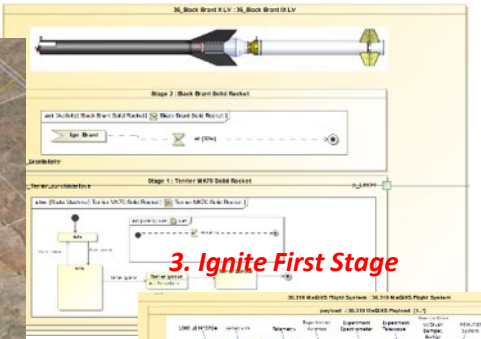
Driver:

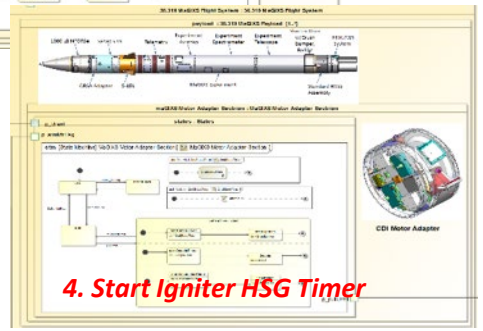
The Sounding Rocket Program would like to ***validate vehicle selection against experimenter needs earlier*** in the project lifecycle in order to reduce design changes later in the lifecycle.

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***.





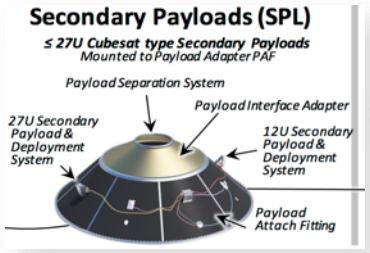


Benefit:

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

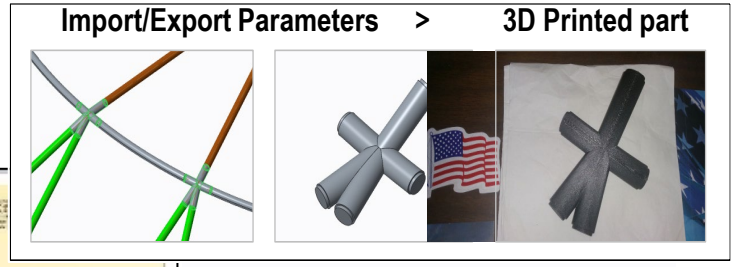


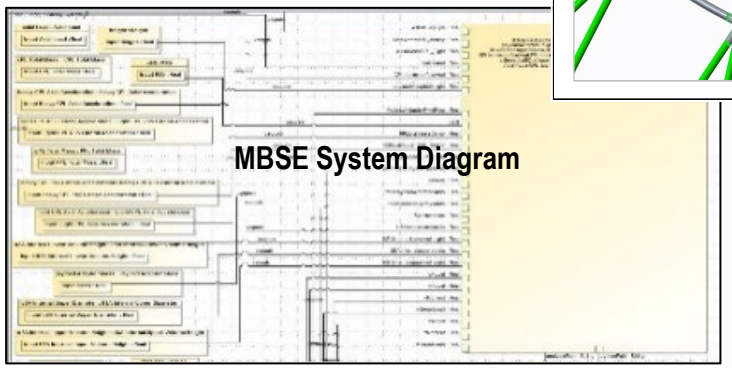
Driver:

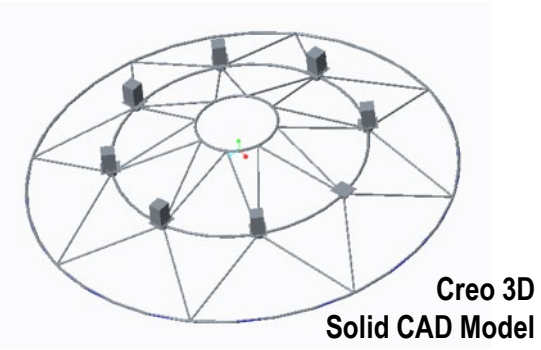
SLS engineering resources are insufficient to ***evaluate 10s-100s of optimized payload adapter options*** for SLS users over life of program.

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.***

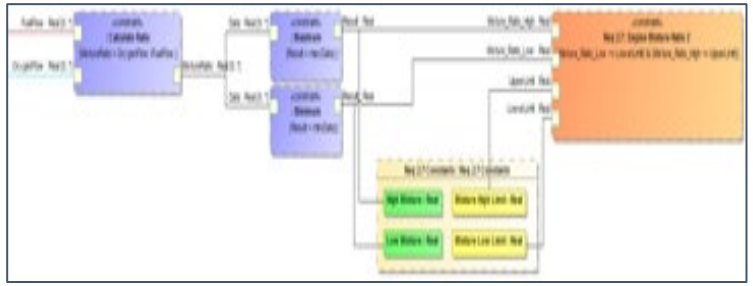
Launch Vehicle Engine Verification and Validation

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***.

Selected MBSE Publications and Presentations (2016-2020)

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- Weiland, K., "Model-Based Systems Engineering Pathfinder 2016 Summary," EMB ViTS, October 20, 2016.
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- 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.
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- 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.
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- 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.
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