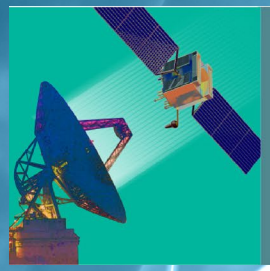
Working Group F Outbrief



25th Ground System Architectures Workshop

Adapting Critical Operations

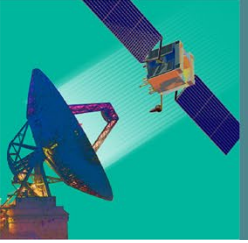
Starts March 1, 2021 | Special Online Series of Events

State-of-the-Practice for Digital Engineering Transformations in Space Mission Ground Systems

Leads:
Theresa Beech,
NASA Goddard Space Flight Center
and Mark McKelvin,
The Aerospace Corporation

March 10, 2021

OTR202100613



Session Goals

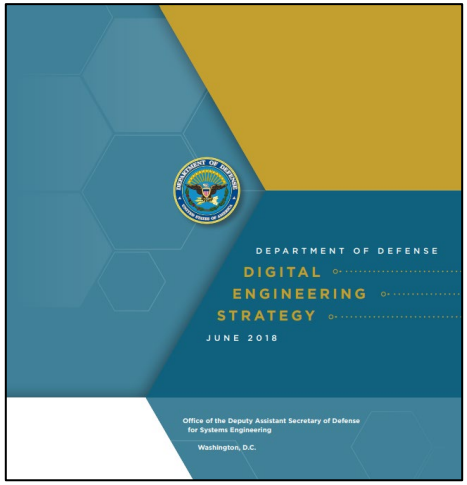
- Collect a set of best practices for leveraging digital engineering to improve decision making on ground system architectures

- Key Questions:
  - *What is the state-of-practice in your organization?*
  - *What is the scope of use in your organization?*
  - *What are major challenges to adoption and application? How are these challenges addressed?*
  - *What are effective and ineffective practices to enable a digital transformation?*

Session Goals

Context: Enabling Digital Transformation

- An integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support life cycle activities from concept through disposal [DoD DE Strategy, 2018].



Use models to inform decision making

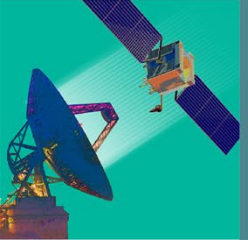
Provide an authoritative source of truth

Leverage innovative technologies to improve practice

Develop and use infrastructure, environments, tools for communication and collaboration

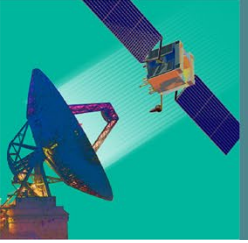
Provide training to transform organizational culture and workforce

Working Group F



Presenters/Panelists

- Presenters
  - *Theresa Beech, NASA Goddard Space Flight Center, "Working Group F Case Study: GMSEC Model-Based Systems Engineering (MBSE) and Ground Systems"*
  - *Slides in Appendix A*



Key Points

Use models to inform decision making

Challenges	Practices
• Providing views of a model for stakeholder consumption instead of complete model details	• Adopt model-view-controller pattern where views are projected from the model to meet stakeholder needs

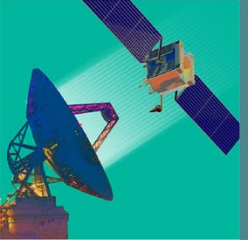
Leverage innovative technologies to improve practice

Challenges	Practices
• Lack of understanding for what the new technologies are (e.g. DevSecOps, agile)	• Provide training to improve awareness and understanding of new technologies

Provide an authoritative source of truth

Challenges	Practices
• Existence and use of an authoritative source of truth (ASOT) is counter to organizational culture • Lack of understanding for what constitutes an ASOT	• Help organizations identify the set of data that they cannot live without • Provide data store with common access across stakeholders

Working Group F



Key Points

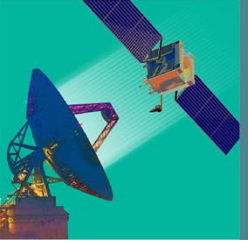
Use of infrastructure, environments, tools for communication and collaboration

Challenges	Practices
• Automation stability requires effort • Tool interoperability • Vendor tool lock-in • Cost of vendor tools • Identifying a multi-functional tool that does everything • Language specification standards are implemented differently across tool vendors • Tool usage is incompatible with organization processes	• Provide opportunities for team members with less experience to use tools • Reduce need for tool interoperability by using less tools • Follow tool interoperability standards • Have tools that are capable of interoperability (e.g. plugins to other tools or by default) • Implement tool transformations • Try tools in expected operating environment before committing

Transform organizational culture and workforce

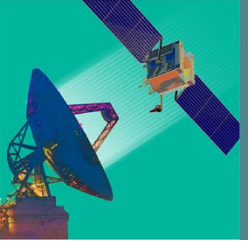
Challenges	Practices
• Learning curve on new approaches to leverage technologies • Effort and time to train • Ineffective documentation for training • Conducting current work while adopting new technologies	• Provision the time to do the training • Create documentation that meets needs of developers and external stakeholder needs • Express the value of change in terms of what stakeholders care about • Develop process improvement plans along with engineering plans • Implement transformation incrementally • Influence the right people

Working Group F



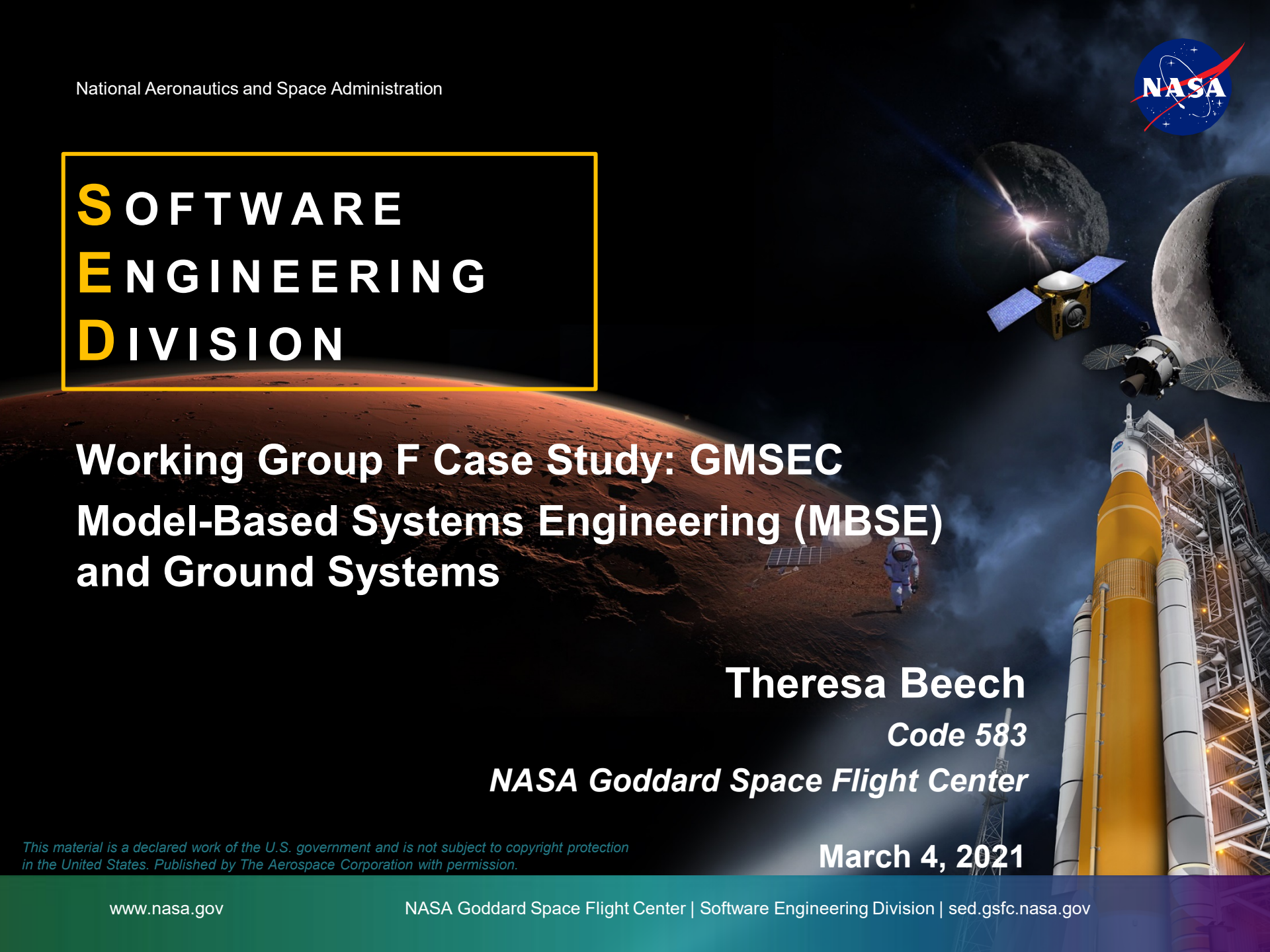
Conclusions

- Challenges to adopt and use tools continue to dominate discussions around digital transformation in ground systems
- Transformation of organizational culture still has considerable challenges, but there are practices that are considered which could assist progress
- Observed less on improving decision making relative to improving traceability of information and access to relevant information



Appendix A: GMSEC Case Study Presentation

National Aeronautics and Space Administration



SOFTWARE ENGINEERING DIVISION

Working Group F Case Study: GMSEC Model-Based Systems Engineering (MBSE) and Ground Systems

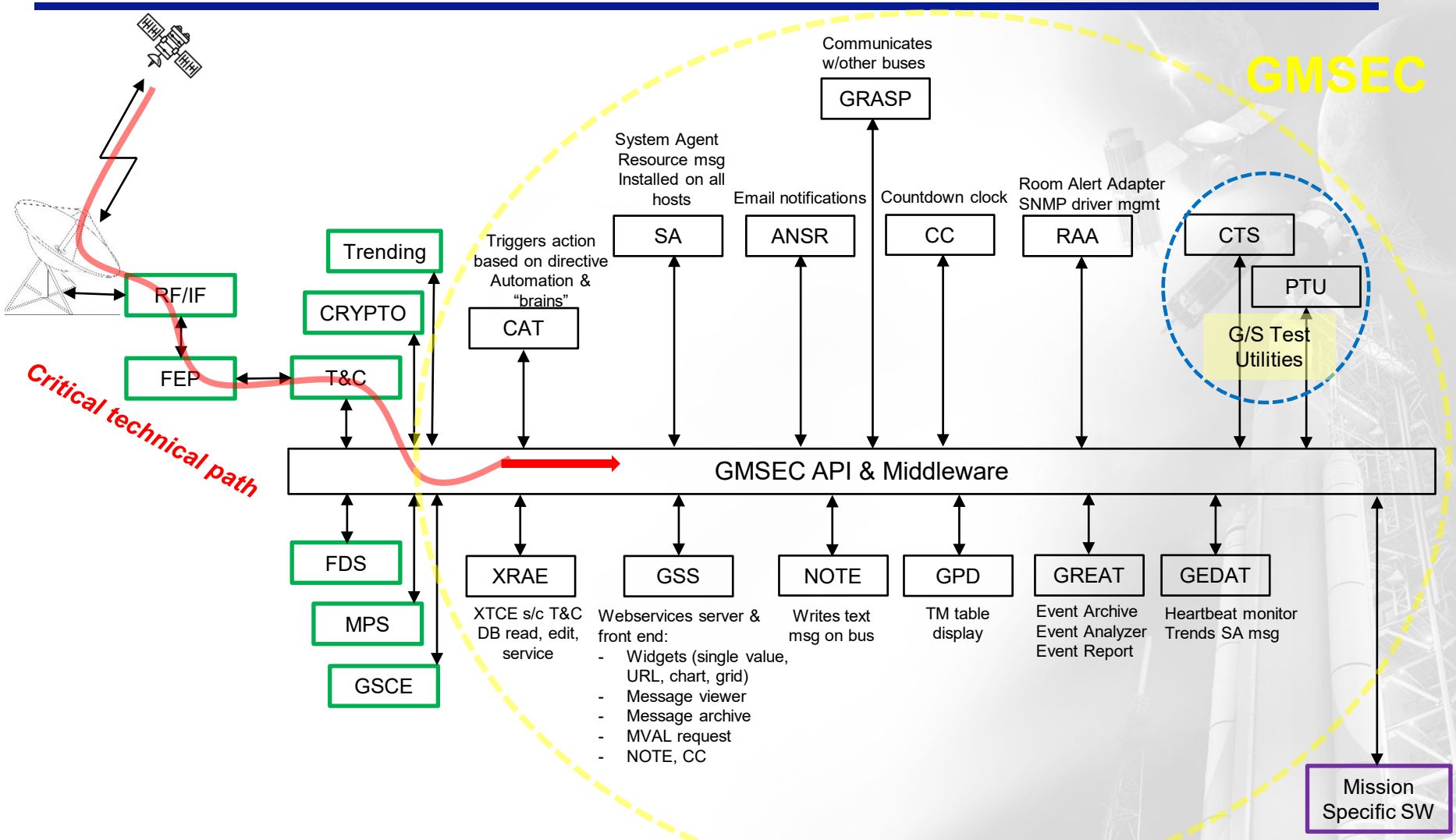
Theresa Beech

Code 583

NASA Goddard Space Flight Center

March 4, 2021

What is GMSEC (Goddard Mission Services Evolution Center)?



GMSEC & Model Based Systems Engineering (MBSE)

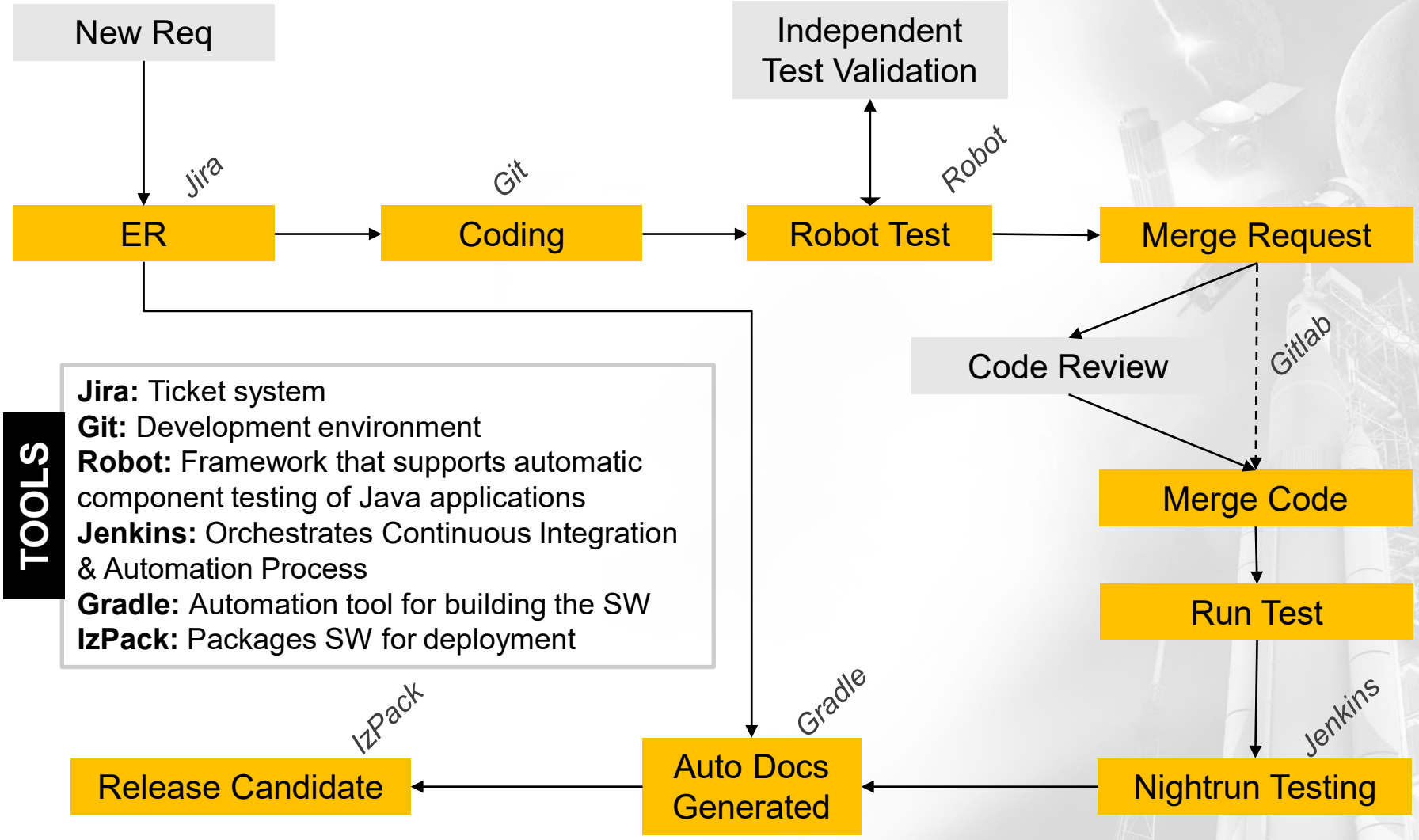
- **What do we mean by MBSE?**
  - **S = Systems, not software (SW) specifically**
- **How do we use MBSE?**
  - **A methodology to help us develop Ground System (G/S) SW which meets the NASA process reqs (NPR)**
  - **Major axes:**
    - **Coding**
    - **Testing**
    - **Tracing**
    - **Document generation**
    - **Requirements (reqs)**
    - **Design**

Automate, automate, automate…

Pick tools well…

Communicate, communicate, communicate…

Component Process Flow: Reqs → Code → Test → Docs Generated



Automated Nightrun Testing

GMSEC Components

SWE-062
SWE-186
SWE-191

Wed 06/10/2020 04:44 AM
noreply@jenkins.gsfc.nasa.gov
Nightly: 18 Successes
To Mortam, Rhea K. (GSFC-583.0)[ASRC FEDERAL SPACE & DEFENSE, INC.]; Beech, Theresa W
Knizhnik, Jessica R. L. (GSFC-5810)

GMSEC Nightly Run Results

SUCCESSFUL: Job 'ansr[115]':
Check console output at "ansr[115]"

SUCCESSFUL: Job 'cat[14]':
Check console output at "cat[14]"

SUCCESSFUL: Job 'cc[113]':
Check console output at "cc[113]"

SUCCESSFUL: Job 'cts[112]':
Check console output at "cts[112]"

SUCCESSFUL: Job 'event-analyzer[102]':
Check console output at "event-analyzer[102]"

SUCCESSFUL: Job 'event-archi...[100]':
Check console output at "event-...[100]"

Wed 06/10/2020 07:30 AM
gsfc-580-nightrun@
2020-06-10 Nightrun re
To Beech, Theresa W. (GSFC-5830)
Cc Whitney, David M. (GSFC-583.0)[E
2020-06-10T11-30-03_full.csv
2 KB

RUN 12773
PASS 12443
FAIL 12
EXCUSE 314
MISFIRE 2
NOFILE 0
TIMEOUT 2
OTHER 0

by host:

gs580s-gu1864
at 2020-06-09T20-08-28
RUN=4070 PASS=3964 FAIL=1 EXCUSE=104 MISFIRE=1 NOFILE=0 TIMEOUT=0 OTHER=0

gs580s-gw10x64
at 2020-06-09T19-42-41

GMSEC API

Jenkins

search

Beech, There

Jenkins

New Item
People
Build History
Project Relationship
Check File Fingerprint
My Views
Disk Usage
Credentials
New View

Build Queue
No builds in the queue.

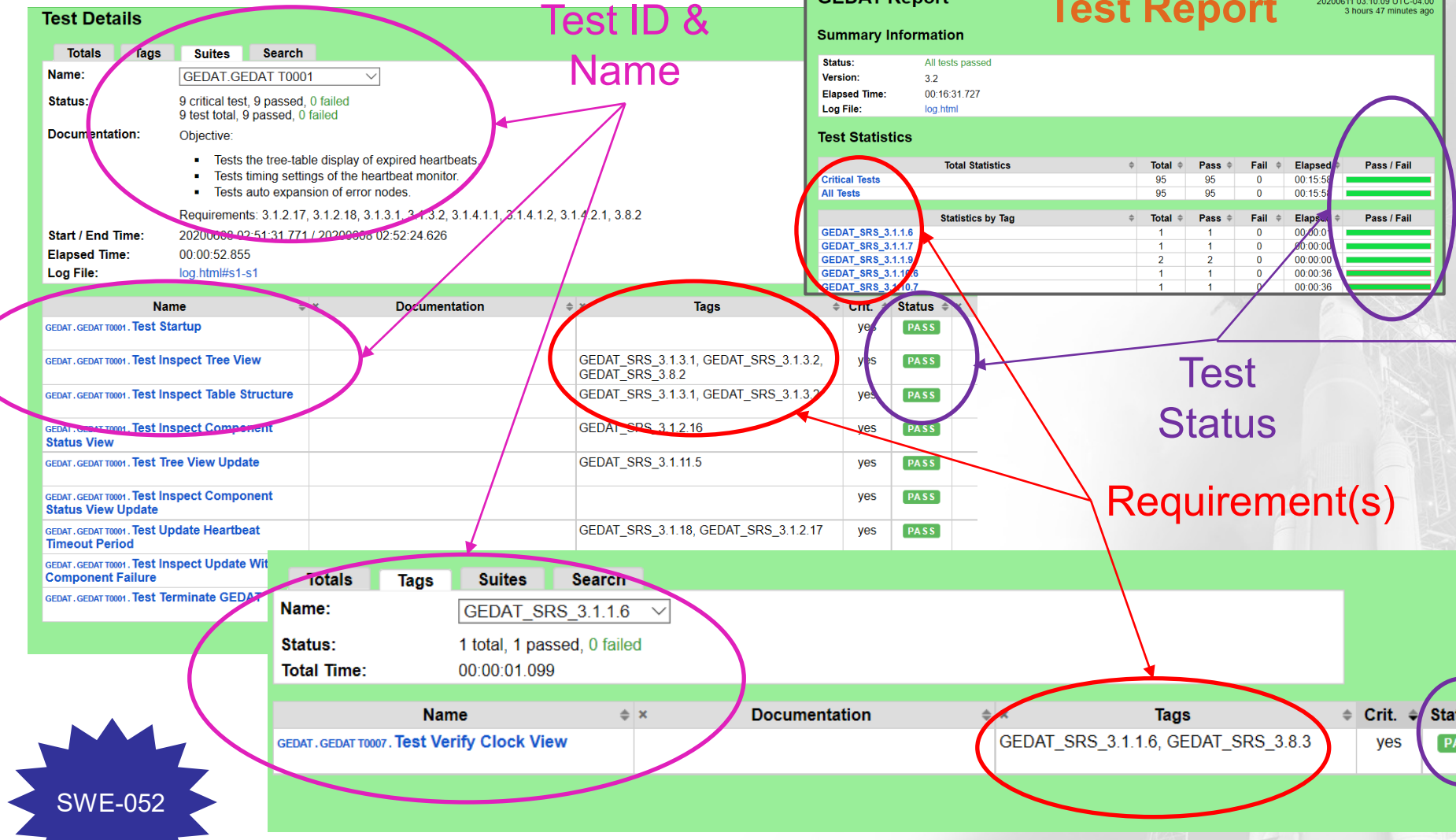
Build Executor Status
master

All | CERES | GMSEC | SC | +

S	W	Name ↓	Last Success	Last Failure	Last Duration	# Issu
		ansr	14 hr - #115	4 days 14 hr - #111	53 min	-
		cat	13 hr - #14	N/A	47 sec	-
		cc	13 hr - #113	22 days - #91	9 min 17 sec	-
		CERES	N/A	N/A	N/A	-
		cts	12 hr - #112	22 days - #90	12 min	-
		DemoHPEJenkins	N/A	1 yr 12 mo - #7	3 min 38 sec	-
		DSM-SBN	N/A	N/A	N/A	-
		email-notifications	14 hr - #114	1 mo 0 days - #77	3 hr 11 min	-
		email_test	10 mo - #1	N/A	0.15 sec	-
		event-analyzer	12 hr - #102	22 days -	31 sec	-

More Robust Testing

Bidirectional Traceability & Test Report



SWE-052

Automated Document Generation: VDD & readme

JIRA Item

SWE-063

GEDAT-4903: C2MS Compliance: ensure C2CX message have correct subject and contents

More consistent documentation

Build Information

JIRA and Confluence AsciiDoc Output

Jira and Confluence Tasks

Document Template

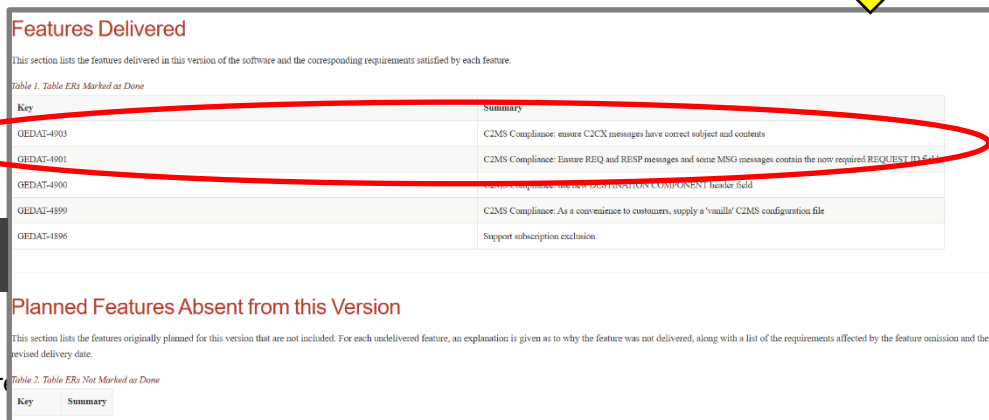
Freemarker Template Task

Intermediate AsciiDoc

AsciiDoctor Task

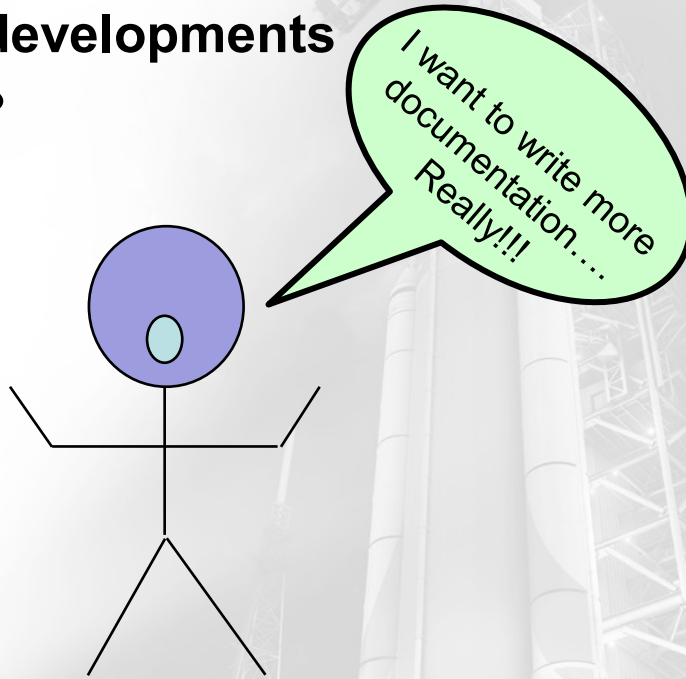
HTML Output

VDD



What about Design & Requirements? 2 Approaches started with 2 Pilot Projects

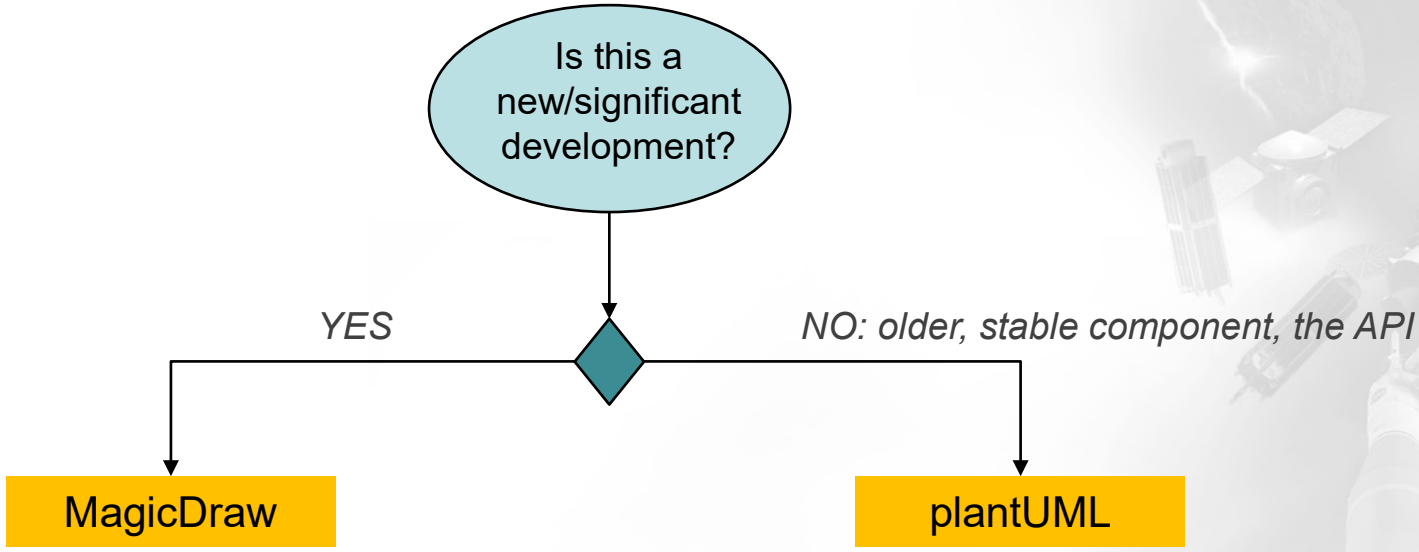
- **THE TRIGGER: Design ⇔ Requirements ⇔ Code**
  - QA audit non-compliance
- **Team discussions**
  - Can we ignore this? What do we want to do? From nothing to …??
  - How to make it useful for us? Old vs. new developments
  - How to minimize the "check the box" cost?
  - Heated discussions with SW Process Improvement team listening in
  - Informal briefings to eng mgmt



…said no engineer ever….

- **Approach decided upon:**
  - Two pilot projects:
    - MagicDraw
    - plantUML

Result: Going Forward w/Both Approaches



- **Decision Factors**
  - ✓ Developer buy-in
  - ✓ Sustainability:
    - ➢ Ease of use, few tools increase adherence to process
    - ➢ Must not be burdensome for developers or a drag on productivity
  - ✓ Usefulness (based on software stage and life cycle)
  - ✓ Satisfy QA requirements

Requirements: Always in MagicDraw

Everything starts with the requirements which are stored in MagicDraw….

1.3.5.2. The GSS Chart Widget shall allow the user to limit the number of points displayed in the plot area of the chart by a time span in hours and minutes.

1.3.5.3. When the limit is reached, the GSS Chart Widget shall drop the oldest point from the display of the chart.

1.3.6. The GSS Chart Widget shall allow the user to clear the plot area of the chart.

1.4. The GSS shall provide the user with a Countdown Clock widget.

1.4.1. The GSS Countdown Clock widget shall display the current time.

1.4.2. The GSS Countdown Clock widget shall allow the user to customize the clock format and time zone.

1.4.3. The GSS Countdown Clock widget shall display the time left until the beginning of an event.

1.4.4. The GSS Countdown Clock widget shall provide the user with two different views:

1.4.4.1. The Next Pass View shall display countdowns to the nearest future event in multiple groups.

1.4.4.2. The Event Countdown View shall display all known upcoming events ordered by event start times.

1.4.5. The GSS Countdown Clock widget shall allow the user to choose which columns are displayed in the event list.

1.4.5.1. The

1.4.6. The GSS C
field.

1.4.6.1. The
particular

Requirements ×

Add New | Add Nested | Add Existing... | Delete

Excel Import Status: New | Updated | Obsolete | Unchanged

#	Name	Text
95	GSS1.12 1.12	The GSS user interface shall have the following structure:
96	GSS1.12.1 1.12.1	The GSS shall have a login page
97	GSS1.12.1.1 1.12.1.1	The login page shall initially display no username
98	GSS1.12.1.2 1.12.1.2	The login page shall not be accessible by a logged in user
99	GSS1.12.1.3 1.12.1.3	The login page shall navigate to the home page
100	GSS1.12.2 1.12.2	The GSS shall have a home page
101	GSS1.12.2.1 1.12.2.1	Before logging in, the home page shall display a login dialog
102	GSS1.12.2.2 1.12.2.2	After logging in, the home page shall display the username
103	GSS1.12.2.3 1.12.2.3	After logging in, the home page shall display the dashboard menu
104	GSS1.12.3 1.12.3	The GSS Support menu:
105	GSS1.12.3.1 1.12.3.1	Shall navigate to the Installation Guide page
106	GSS1.12.3.2 1.12.3.2	Shall navigate to the User Guide page
107	GSS1.12.4 1.12.4	The GSS Administration menu:
108	GSS1.12.4.1 1.12.4.1	Shall load user management
109	GSS1.12.4.2 1.12.4.2	Shall navigate to the metrics page
110	GSS1.12.4.3 1.12.4.3	Shall navigate to the health page
111	GSS1.12.4.4 1.12.4.4	Shall navigate to the logs page
112	GSS1.12.4.5 1.12.4.5	Shall navigate to the API page
113	GSS1.12.5 1.12.5	The GSS Account menu:
114	GSS1.12.5.1 1.12.5.1	Shall navigate to the settings page

Requirements are housed in MagicDraw for both approaches

System requirements are traced to components

RTM ×

Delete

Legend
Refine

GSS1.9 1.9
GSS1.10 1.10
GSS1.11 1.11
GSS1.12 1.12
GSS1.12.1 1.12.1
GSS1.12.1.1 1.12.1.1
GSS1.12.1.2 1.12.1.2
GSS1.12.1.3 1.12.1.3
GSS1.12.2 1.12.2
GSS1.12.2.1 1.12.2.1
GSS1.12.2.2 1.12.2.2
GSS1.12.2.3 1.12.2.3
GSS1.12.3 1.12.3
GSS1.12.3.1 1.12.3.1
GSS1.12.3.2 1.12.3.2

SystemRequirements [Read-Only] ×

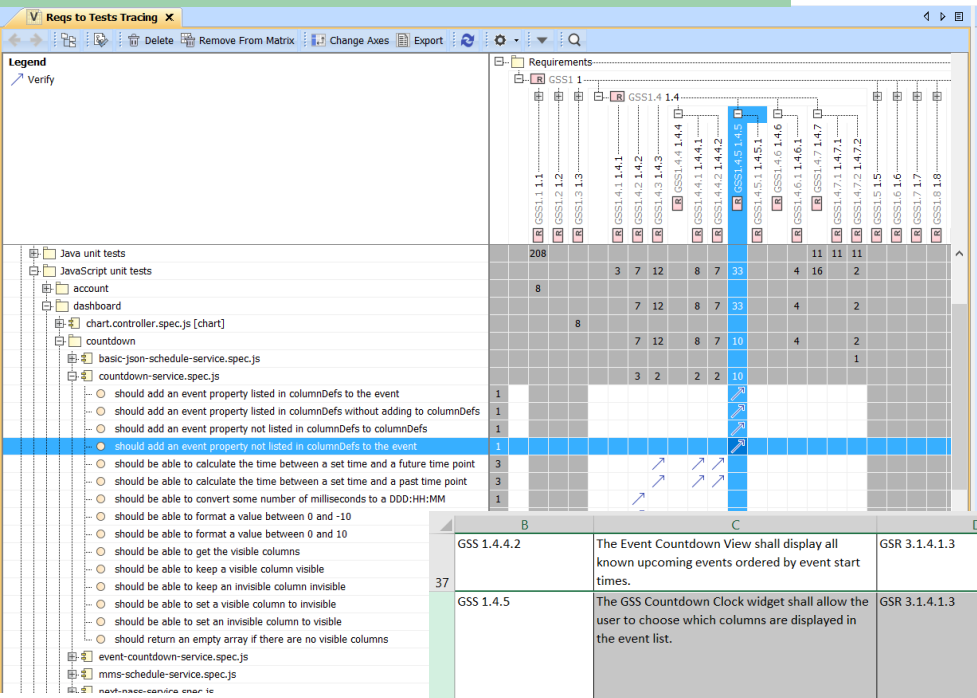
Add New | Add Nested

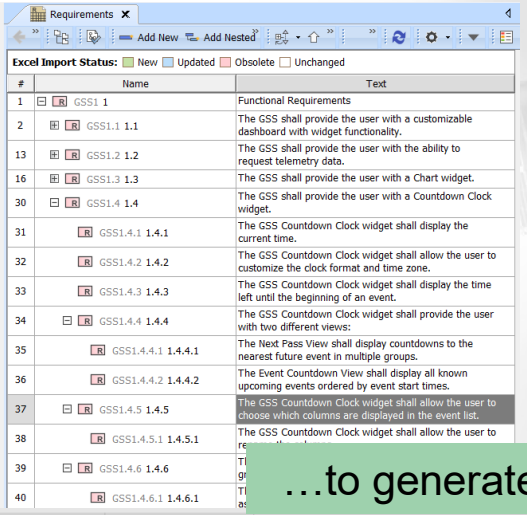
Criteria
Scope (optional): Filter:

#	Name	Text
1	GSR3 3	General Requirements
2	GSR3.1 3.1	Functional Requirements
3	GSR3.1.1 3.1.1	GMSEC System shall enable inter-application communication
6	GSR3.1.2 3.1.2	GMSEC System shall enable inter-application communication among two or more GMSEC implementations
7	GSR3.1.3 3.1.3	GMSEC System shall provide an API that normalizes common message-oriented middleware interfaces
15	GSR3.1.4 3.1.4	GMSEC System shall define capabilities of compliant GMSEC components
16	GSR3.1.4.1 3.1.4.1	GMSEC System components shall adhere to standardized message formats as defined in OMG C2MS
17	GSR3.1.4.1.1 3.1.4.1.1	GMSEC System component categories shall include: telemetry and command
18	GSR3.1.4.1.2 3.1.4.1.2	archive
19	GSR3.1.4.1.3 3.1.4.1.3	monitoring
20	GSR3.1.4.1.4 3.1.4.1.4	situational awareness
21	GSR3.1.4.1.5 3.1.4.1.5	alerting/notification
22	GSR3.1.4.1.6 3.1.4.1.6	analysis and trending
23	GSR3.1.4.1.7 3.1.4.1.7	automation
24	GSR3.1.4.1.8 3.1.4.1.8	testing/validation
25	GSR3.1.4.1.9 3.1.4.1.9	GMSEC System components shall adhere to messages defined for each category of component
26	GSR3.1.4.1.10 3.1.4.1.10	GMSEC System shall adhere to message interactions for each defined category of component
27	GSR3.1.5 3.1.5	GMSEC System shall verify compliance of GMSEC components
30	GSR3.1.6 3.1.6	GMSEC System shall provide middleware access via a web-server/browser architecture.

Testing and Tracing in MagicDraw

Requirements are traced to tests…





…to generate traceability matrices

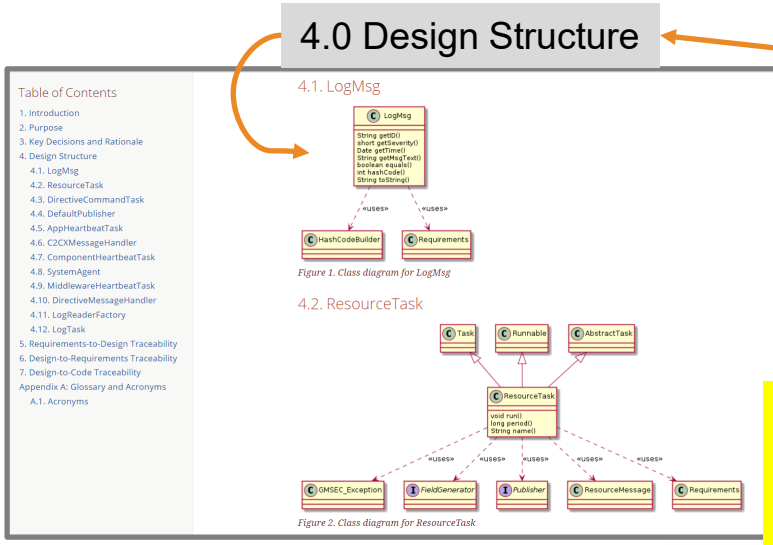
	B	C	D	E	F
37	GSS 1.4.4.2	The Event Countdown View shall display all known upcoming events ordered by event start times.	GSR 3.1.4.1.3	Test	Tests::Portal::End to end (JavaScript) tests::dashboard::countdown::countdown.spec.js::should be able to remain on e Tests::Portal::End to end (JavaScript) tests::dashboard::countdown::countdown.spec.js::should be able to switch to ev Tests::Portal::JavaScript unit tests::dashboard::countdown::countdown-service.spec.js::should be able to calculate the
38	GSS 1.4.5	The GSS Countdown Clock widget shall allow the user to choose which columns are displayed in the event list.	GSR 3.1.4.1.3	Test	countdown-service.spec.js::**should add an event property not listed in columnDefs to the event** countdown-service.spec.js::should add an event property listed in columnDefs to the event countdown-service.spec.js::should add an event property listed in columnDefs without adding to columnDefs countdown-service.spec.js::should add an event property not listed in columnDefs to columnDefs countdown-service.spec.js::should be able to get the visible columns countdown-service.spec.js::should be able to keep a visible column visible countdown-service.spec.js::should be able to keep an invisible column invisible countdown-service.spec.js::should be able to set a visible column to invisible countdown-service.spec.js::should be able to set an invisible column to visible countdown-service.spec.js::should return an empty array if there are no visible columns
39	GSS 1.4.5.1	The GSS Countdown Clock widget shall allow the user to rename the columns.	GSR 3.1.4.1.3	Test	Tests::Portal::End to end (JavaScript) tests::dashboard::countdown::countdown.spec.js::should be able to open the co Tests::Portal::End to end (JavaScript) tests::dashboard::countdown::countdown.spec.js::should be able to pop open th
40	GSS 1.4.6	The GSS Countdown Clock widget shall allow the user to group events by a particular field.	GSR 3.1.4.1.3	Test	Tests::Portal::End to end (JavaScript) tests::dashboard::countdown::countdown.spec.js::should be able to pop open th Tests::Portal migrator::Java unit tests::CountdownParamsMigration1_0to1_1Test.java::testValidUpgrade
41	GSS 1.4.6.1	The GSS Countdown Clock widget shall allow the user to assign groups a particular color for visual effect.	GSR 3.1.4.1.3	Test	Tests::Portal::End to end (JavaScript) tests::dashboard::countdown::countdown.spec.js::should be able to open the co Tests::Portal::End to end (JavaScript) tests::dashboard::countdown::countdown.spec.js::should be able to pop open th Tests::Portal::JavaScript unit tests::dashboard::countdown::event-countdown-service.spec.js::should ensure all events
42	GSS 1.4.7	The GSS Countdown Clock widget shall keep track of events for use by its other functions.	GSR 3.1.4.1.3	Test	Tests::Portal::Java unit tests::web::rest::CountdownEventsResourceIntTest.java::checkUidIsRequired Tests::Portal::Java unit tests::web::rest::CountdownEventsResourceIntTest.java::createCountdownEvents Tests::Portal::Java unit tests::web::rest::CountdownEventsResourceIntTest.java::getAllCountdownEvents
43	GSS 1.4.7.1	The GSS Countdown Clock widget shall allow the user to add events by creating a custom event.	GSR 3.1.4.1.3	Test	Tests::Portal::Java unit tests::web::rest::CountdownEventsResourceIntTest.java::checkUidIsRequired Tests::Portal::Java unit tests::web::rest::CountdownEventsResourceIntTest.java::createCountdownEvents Tests::Portal::Java unit tests::web::rest::CountdownEventsResourceIntTest.java::getAllCountdownEvents

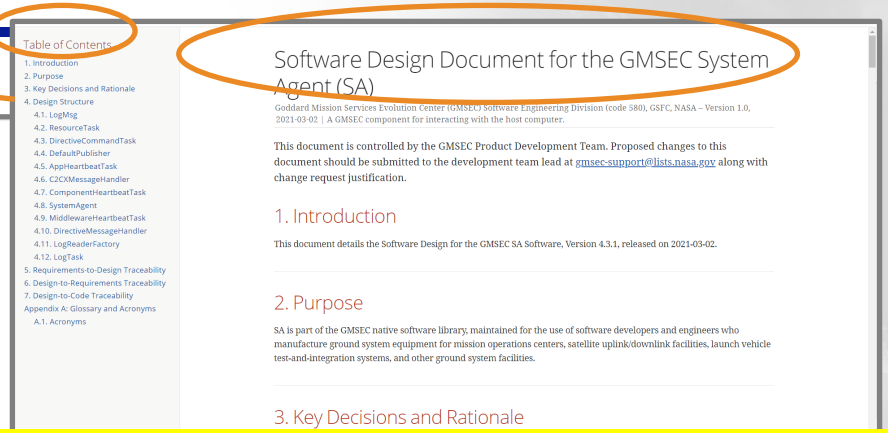
Requirements to Tests | Tests to Requirements

Ready | Average: 35 | Count: 6 | Sum: 35 | 100%

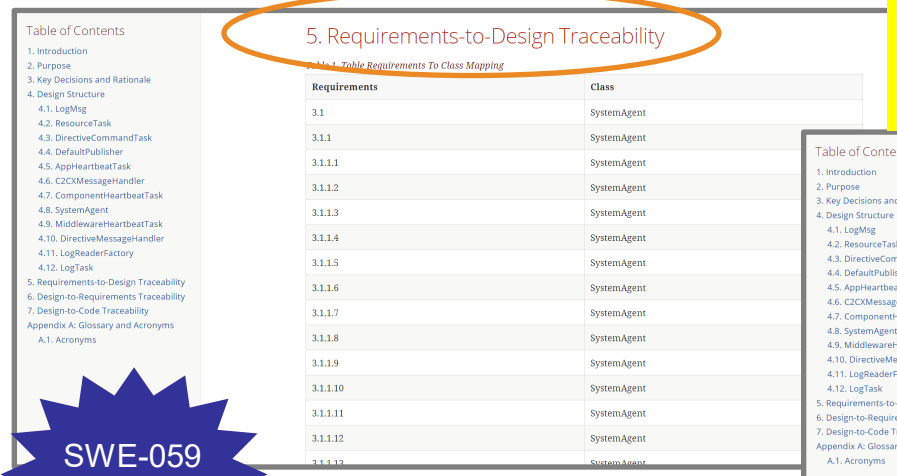
SWE-059
SWE-064

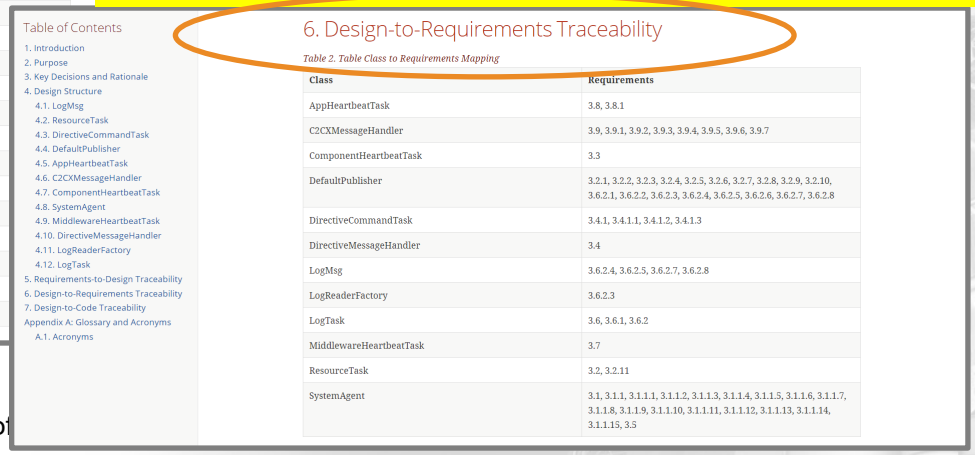
plantUML: Design <=> Requirements <=> Code





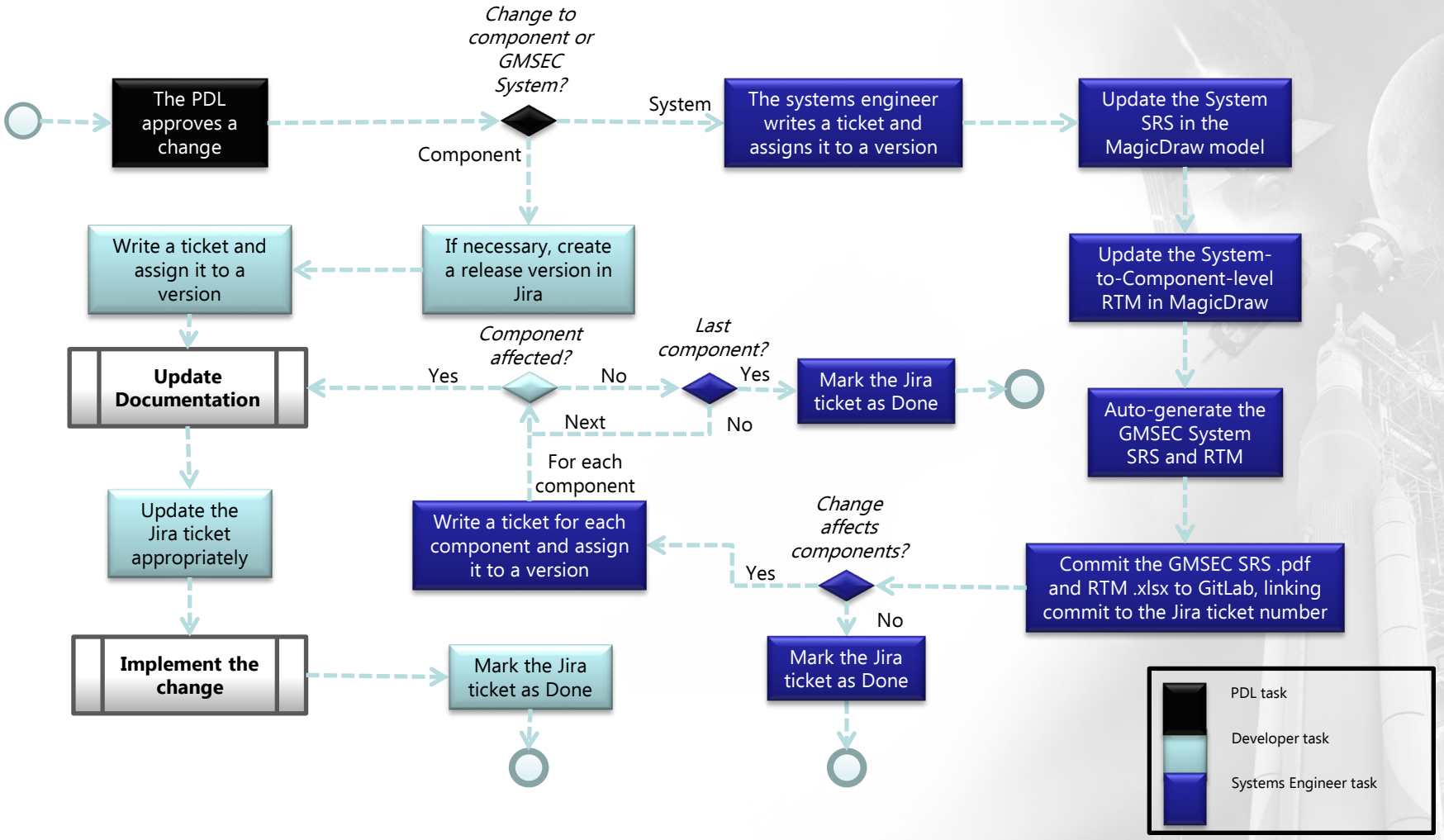
SDD template w/component name & version, API version
1) Developer instruments code w/reqs
2) Java classes scanned for Java annotation w/reqs
3) Scan complete => bidirectional traceability
4) plantUML file is generated for each class
5) plantUML tool converts plantUML files => class diagrams
6) SDD template + traceability tables + images => 1 doc
7) asciidoctor converts doc to HTML

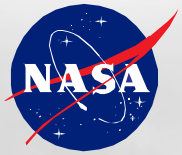




SWE-059
SWE-064

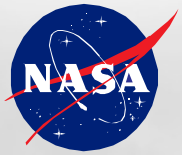
GMSEC Process Diagram



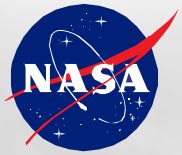


Artifact Checklist

- System Requirements Specification (SRS)
- Component SRS
- Component SW Design Document (SDD)
- Code
- Tests
- RTM System ←→ Component requirements
- RTM Requirements ← → Design ← → Code
- RTM Requirements ← → Tests



Background Information

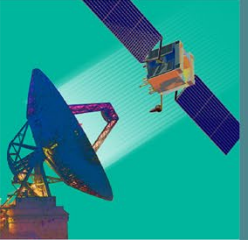


Acronyms

ANSR	Alert Notification System Router
API	Application Programming Interface
C2MS	Command & Control Message Specification
CAT	Criteria Action Tool
CC	Countdown Clock
CCSDS	Consultative Committee on Space Data Standards
CFDP	CCSDS File Data Protocol
CMD	Command
COTS	Commercial Off The Shelf
CTS	Compliance Test Suite
DoD	Department of Defense
ER	Enhancement Request
FDS	Flight Dynamics System
FEP	Front End Processor (aka Baseband Equipment)
GEO	Geostationary Earth Orbit
GMSEC	Goddard Mission Services Evolution Center
GOTS	Government Off The Shelf
GPD	GMSEC Parameter DIsplay
GREAT	GMSEC Reusable Events Analysis Toolkit
GSCE	Ground System Control Equipment
GSFC	Goddard Space Flight Center
GSS	GMSEC Services Suite
HEEO	Highly Elliptical Earth Orbit
hk	Housekeeping telemetry

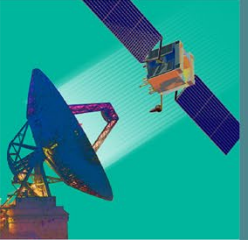
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
MOC	Mission Operations Center
MPS	Mission Planning System
NPR	NASA Process Requirement
QA	Quality Assurance
PDL	Product Development Lead
P/L	Payload
PTU	Performance Test Utility
RAA	Room Alert Adapter
RF/IF	Radiofrequency/Intermediate Frequency
RTM	Requirements Traceability Matrix
SA	System Agent
S/C	Spacecraft
SDD	SW Design Document
SLE	Space Link Extension
SRS	Software/System Requirements Specification
SW	Software
SWE	Software Engineering requirement in the NPR
T&C	Telemetry & Command
VDD	Version Design Document
XML	eXtensible Markup Language
XRAE	XTCE Reader And Editor
XTCE	XML Telemetric & Command Exchange

GMSEC Mini-MOC (aka Big Bertha)



Appendix B: Collected Data

	Challenges/Mitigations	Effective/Ineffective Practices
Use of Models for Decision making	* getting something out of a model for stakeholders to review * accessibility to reveiwers as opposed to authors of the model	* take an approach to generate views or projections that capture what the reviewer are interested in instead of the entire details of the model
Provide ASOT	* The basic concept of having an ASOT is very foreign (and counter to some organizational cultures) and they are still debating how	* provide data store with common access across stakeholders * What data can your program not live without? Present this question to
Leverage innovative technologies to improve practice	* understanding the new approaches e.g. devsecops, agile, due to resistance	* training on usage, increase awareness



Appendix B: Collected Data

	Challenges/Mitigations	Effective/Ineffective Practices
Infrastructure, env, tools for communication and collaboration	* effort to make automation stable * effort from automated to not-automated * getting tools to talk to one another * tool lock in * cost of tools, what about cost to NOT doing things? * finding a tool to do everything is problematic * standards are not really standards, there is ambiguity present and the degree of standardization needs clarification * contracts might constrain use of tools that may not work out * tools and processes not working well together	* provide hands on use of tools by sr members of team rather than let jr people do the work with tools * use less number of tools as possible * use requirements tool for allocation, derivation, tracing etc. then when need to pull into modeling tool * how to manage tool lock in? * standardization - tools should follow industry standards for tool interoperability * having tools that are capable of multiple functions as opposed to tools that do not interoperate by default

Appendix B: Collected Data

	Challenges/Mitigations	Effective/Ineffective Practices
provide training and transform culture and workforce	* training new people to learn the technologies and it takes time and effort; learning curve; (mitigations) just do the training; documentation for training is not effective - just go read the spec; * conduct current work while changing technology	* create docs for the developers, not just docs needed as part of deliverables - essentially need to meet developers' needs and external needs. * express value of change in terms of what the stakeholder cares about * tool transformations * process improvement plans and engineering plans with relationships to bring people along as opposed to do it all at once * try out tools first, to see if they work as you expect them to within your environment before committing. * identify key people to convince (influence the right people)
OTHER	* Scaling from small teams/numbers to larger scale * people, human/organizational aspects * processes more difficult than tools * complicated interplay between tools, processes, environment (constraints)	