UAS Service Suppliers

Development of specifications, tests, and implementations in parallel

Joseph Rios
FAA V+V Summit
19 Sept 2019

Low Altitude UAS Operations

FAA small UAS forecast: 2.4M hobbyists, 450K commercial by 2022

Over 1M registered UAS Operators currently

Vehicles are automated and airspace integration is necessary

New entrants desire access and flexibility for operations

Current users want to ensure safety and continued access

Regulators need a way to put safety structures in airspace

Operational concept being developed to address beyond-visual-line-of-sight (BVLOS) UAS operations at low altitude, not controlled by ATC/ATM

What is UAS Traffic Management?

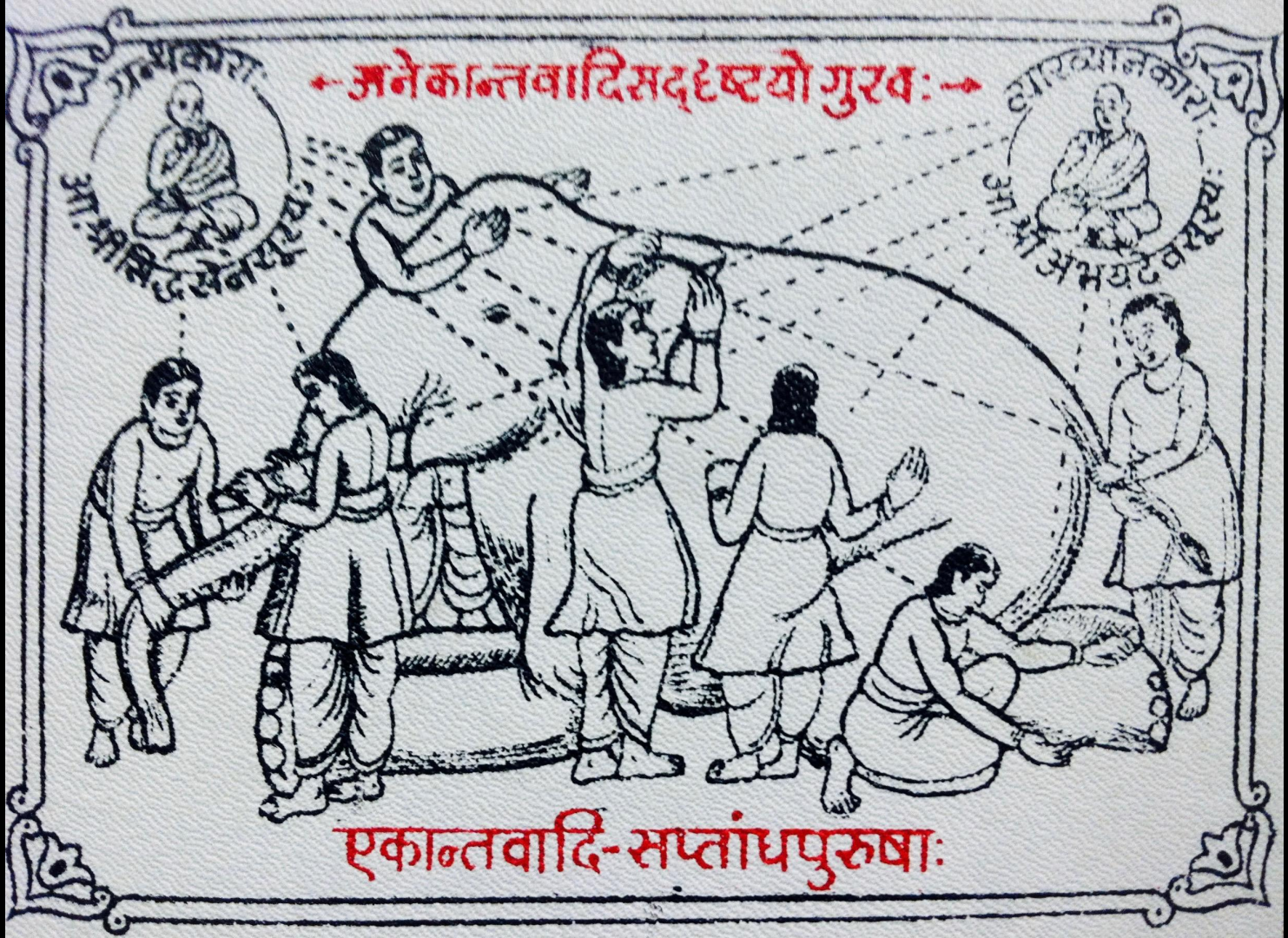
UTM is an "air traffic management" ecosystem for small UAS in low altitude airspace

UTM utilizes industry's ability to supply services under FAA's regulatory authority where these services do not exist.

UTM development will ultimately identify services, roles/responsibilities, information architecture, data exchange protocols, software functions, infrastructure, and performance requirements to enable the management of low-altitude UAS operations.

Transparency **Security** **Safety** **Commerce** **Scalability**

NASA UTM Concept and R+D...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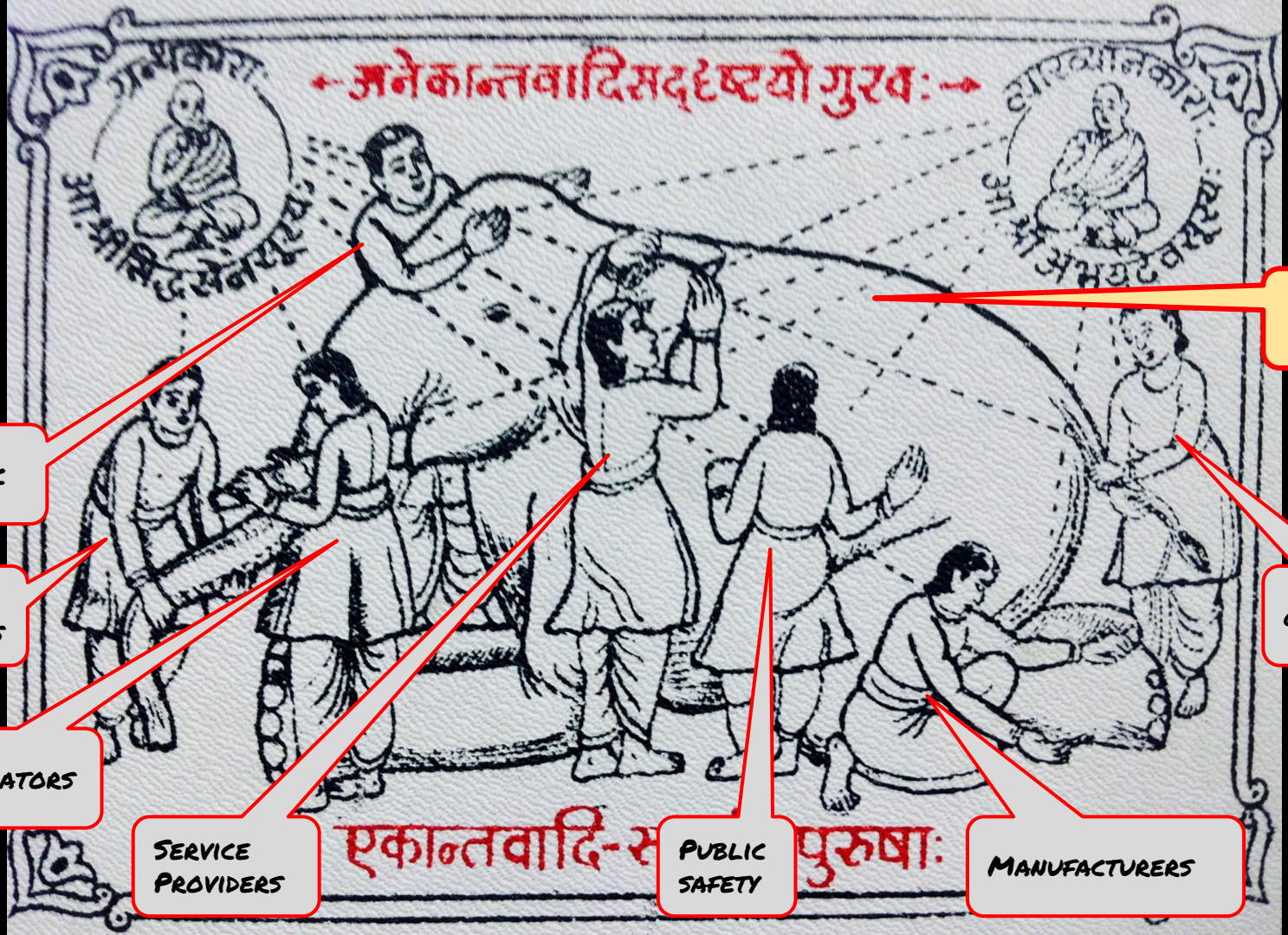
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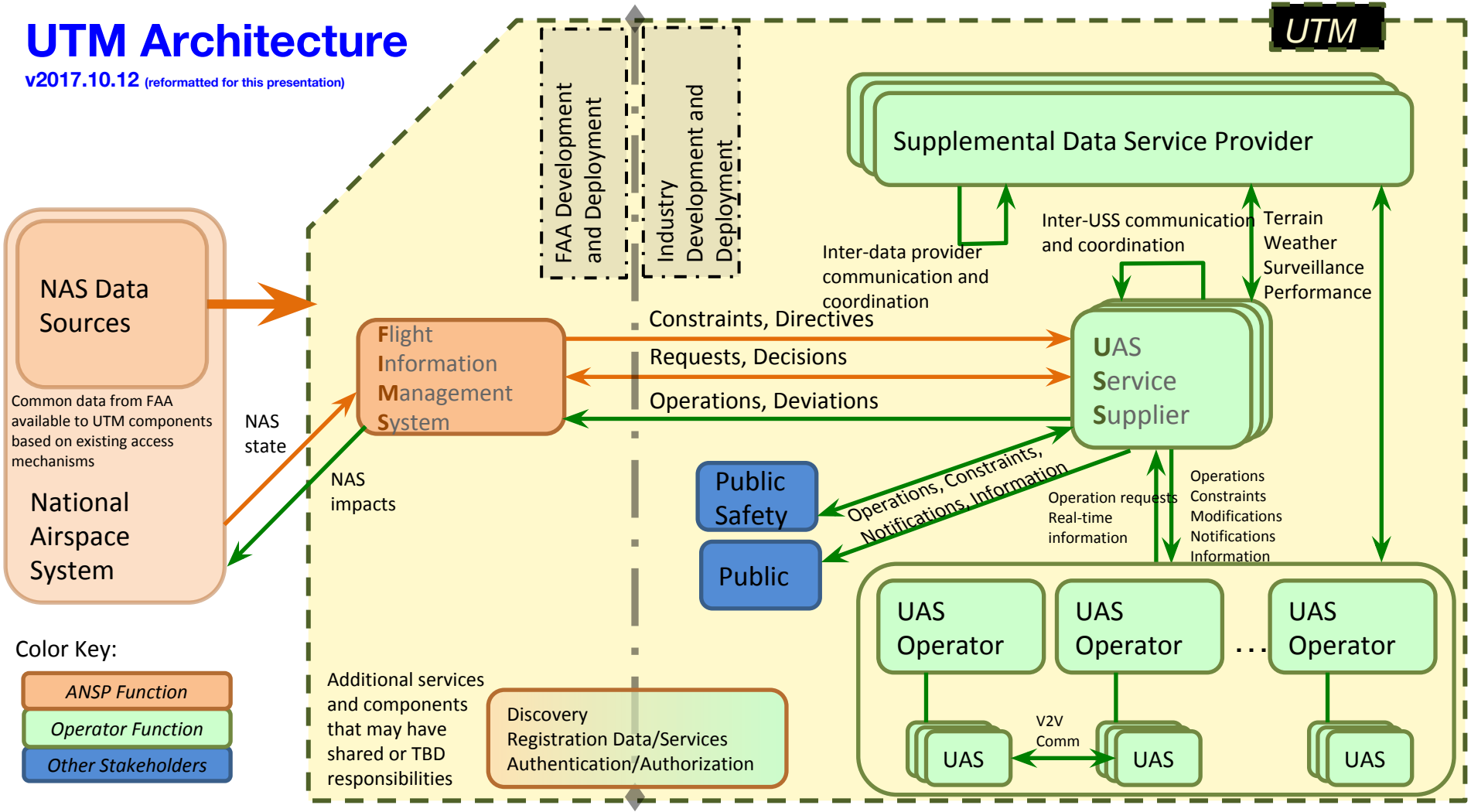
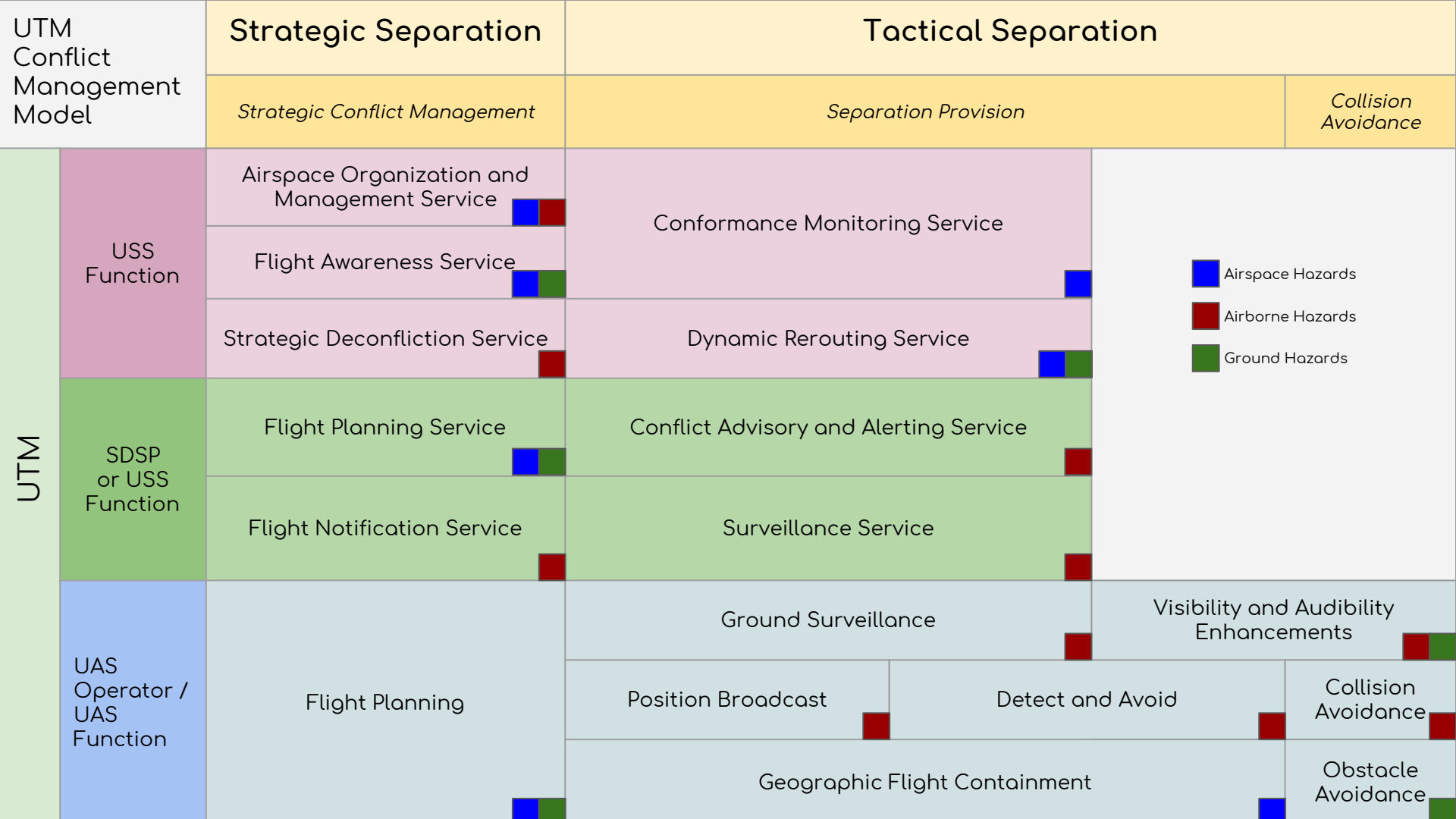
UTM
PUBLIC
UAS PILOTS
REGULATORS
SERVICE PROVIDERS
PUBLIC SAFETY
MANUFACTURERS
OPERATORS

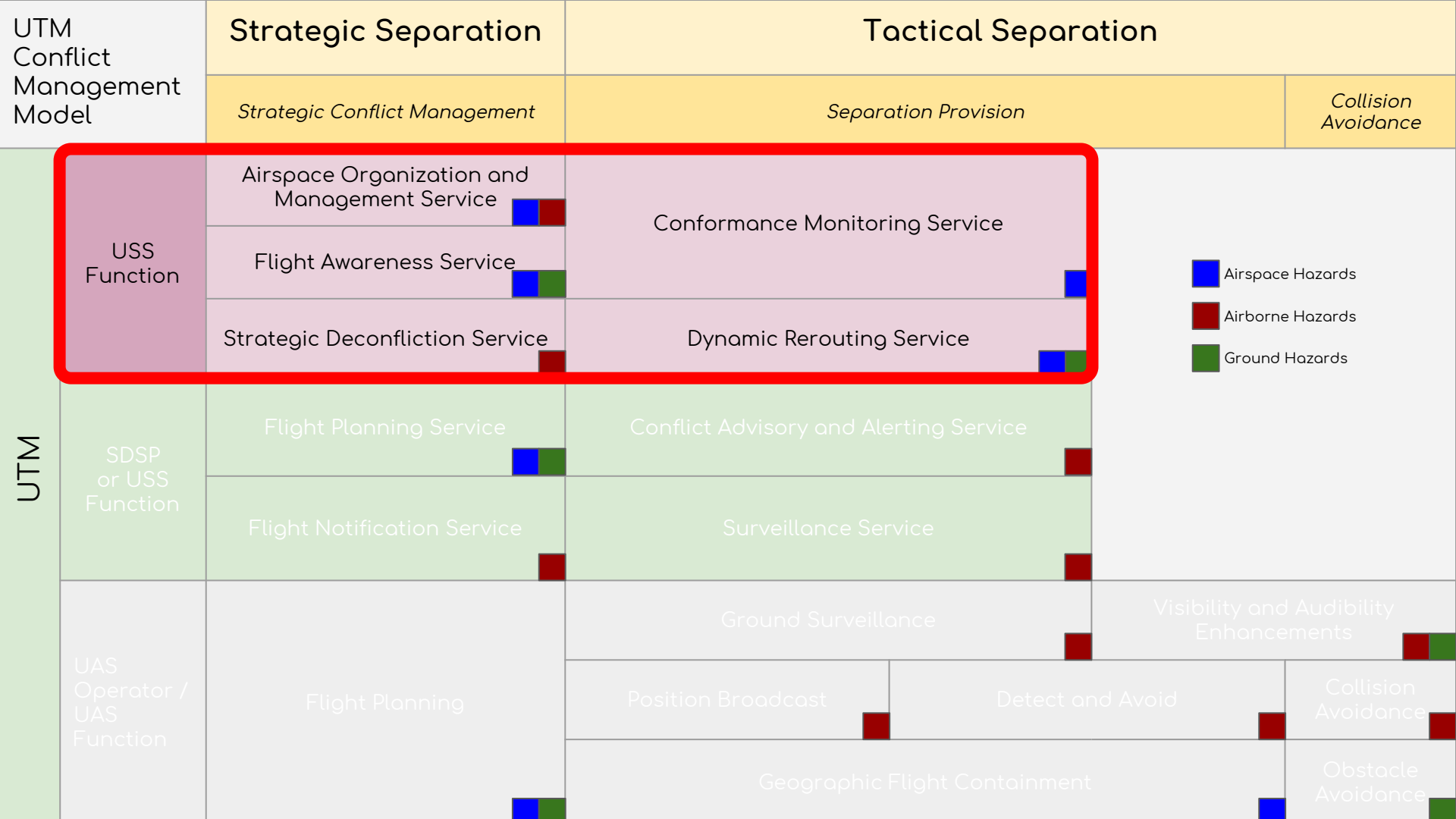
UTM core operating principles

UTM Architecture

v2017.10.12 (reformatted for this presentation)




UTM Conflict Management Model
Strategic Separation
Tactical Separation
Strategic Conflict Management
Separation Provision
Collision Avoidance
UTM
USS Function
SDSP or USS Function
UAS Operator / UAS Function
Airspace Organization and Management Service
Flight Awareness Service
Strategic Deconfliction Service
Conformance Monitoring Service
Dynamic Rerouting Service
Flight Planning Service
Flight Notification Service
Conflict Advisory and Alerting Service
Surveillance Service
Flight Planning
Ground Surveillance
Visibility and Audibility Enhancements
Position Broadcast
Detect and Avoid
Collision Avoidance
Geographic Flight Containment
Obstacle Avoidance
Airspace Hazards
Airborne Hazards
Ground Hazards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Technical Capability Levels (TCL)

Risk-based development and test approach

TCL 1

- Remote Population
- Low Traffic Density
- Rural Applications
- Multiple VLOS Operations
- Notification-based Operations

TCL 2

- Sparse Population
- Low-Mod Traffic Density
- Rural / Industrial Applications
- Multiple BVLOS Operations
- Tracking and Operational Procedures

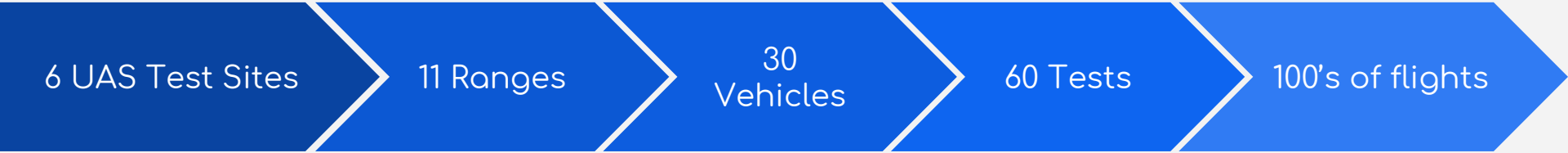
TCL 3

- Moderate Population
- Moderate Traffic Density
- Suburban Applications
- Mixed Operations
- Vehicle to Vehicle Communication
- Public Safety Operations

TCL 4

- Dense Population
- High Traffic Density
- Urban Applications
- Dense BVLOS Operations
- Large Scale Contingency Management

TCL3 Field Testing...



- Alaska
- Nevada
- North Dakota
- New York
- Texas
- Virginia

Ranges covered a wide variety of conditions

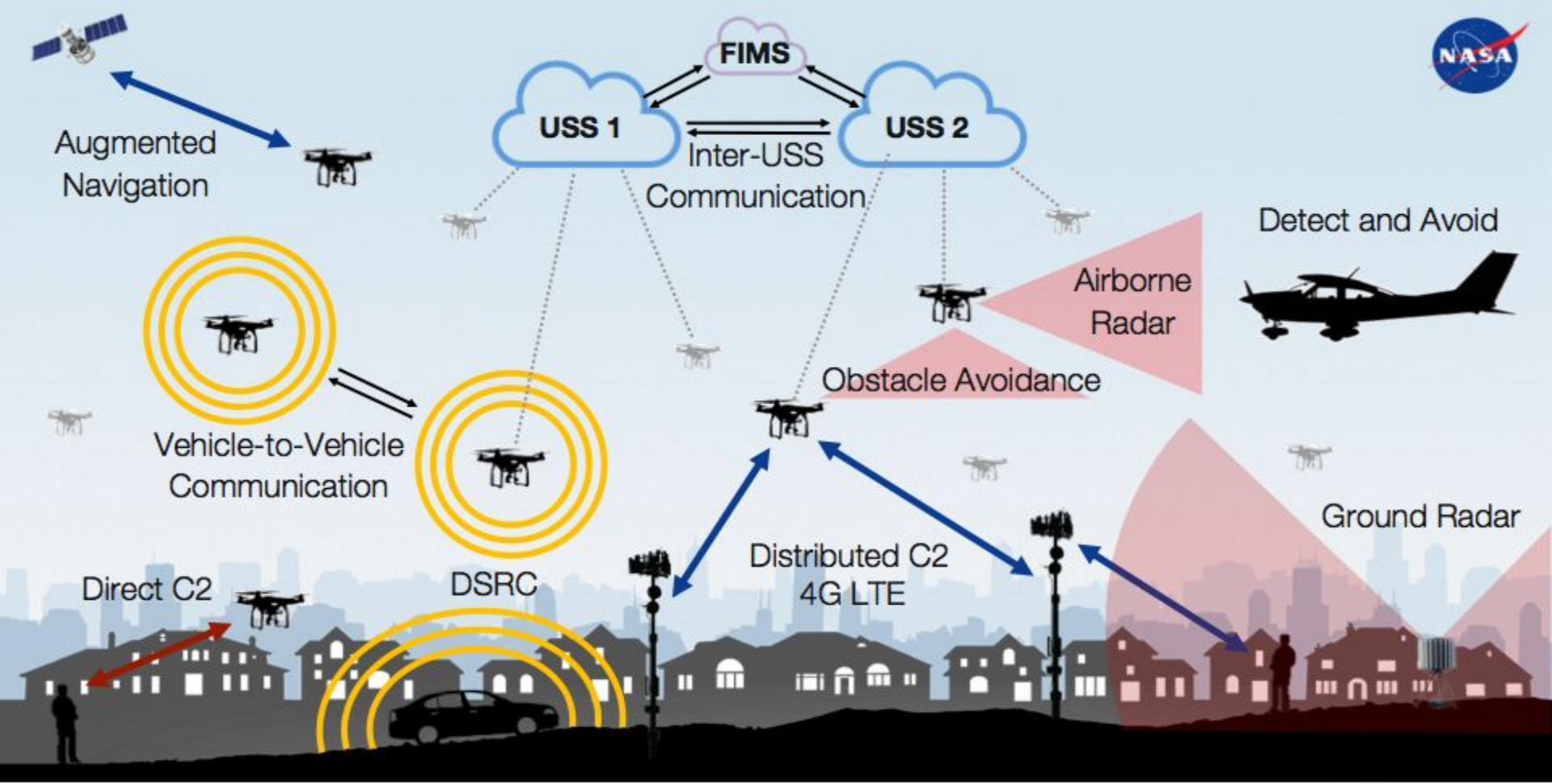
- Fixed wings
- Multirotor
- Hybrids
- Helicopters

- Comm & Nav
- Sense and Avoid
- Data Exchange
- Concepts

Multiple mappings of test sites and vehicles and tests.

TCL3 Flight Testing Overview

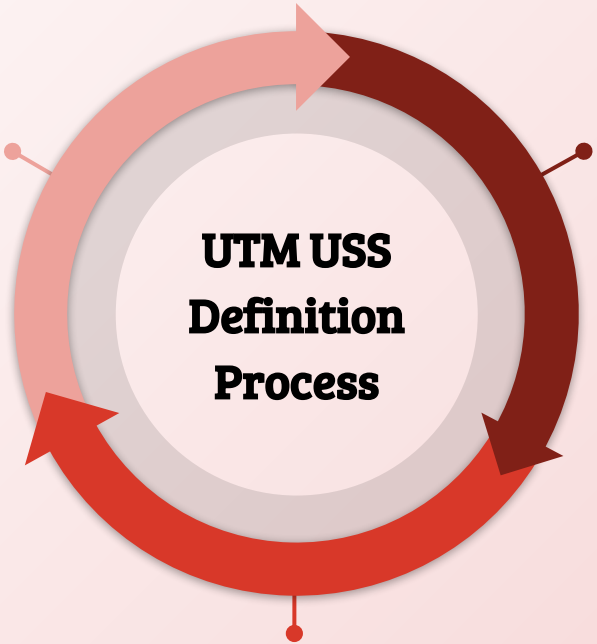
Executed February through May 2018



Technical Capability Level 3 Flight Tests

TCL 3 Flight Testing

UTM Requirements Development Process...



Testing

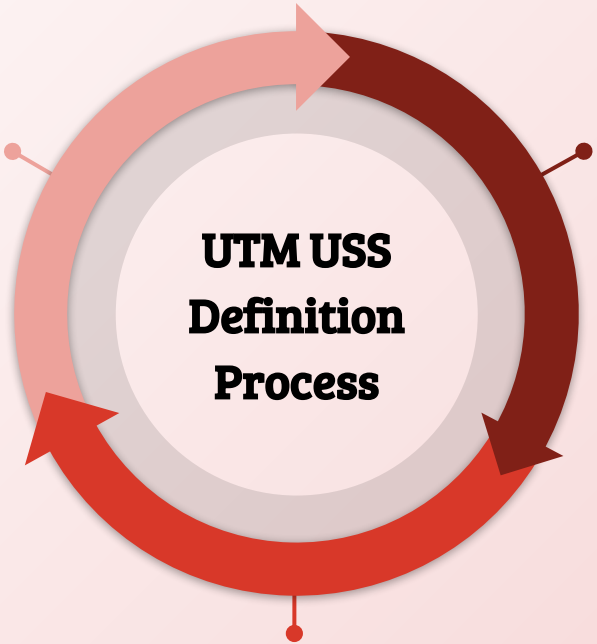
Driven toward Collaborative Sims
Realized by Flight Tests

Concept Development

Formalized by Research Transition Team
Fortified by Industry Working Groups

Software Implementation

Guided by Use Cases
Solidified by APIs



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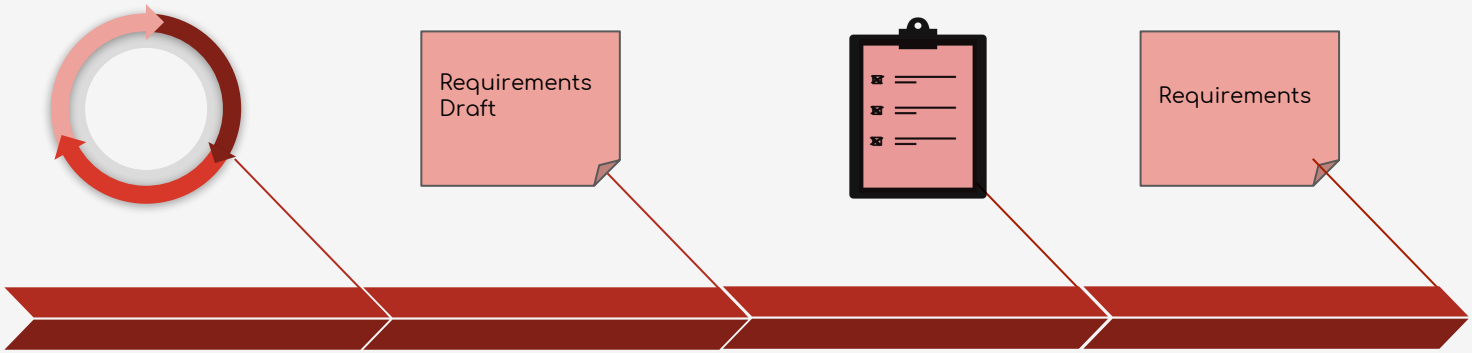
For better or worse, the software development of USSs has been ahead of the other cycle elements for the majority of UTM development.

Process of formalizing a concept, feature, or service within UTM…



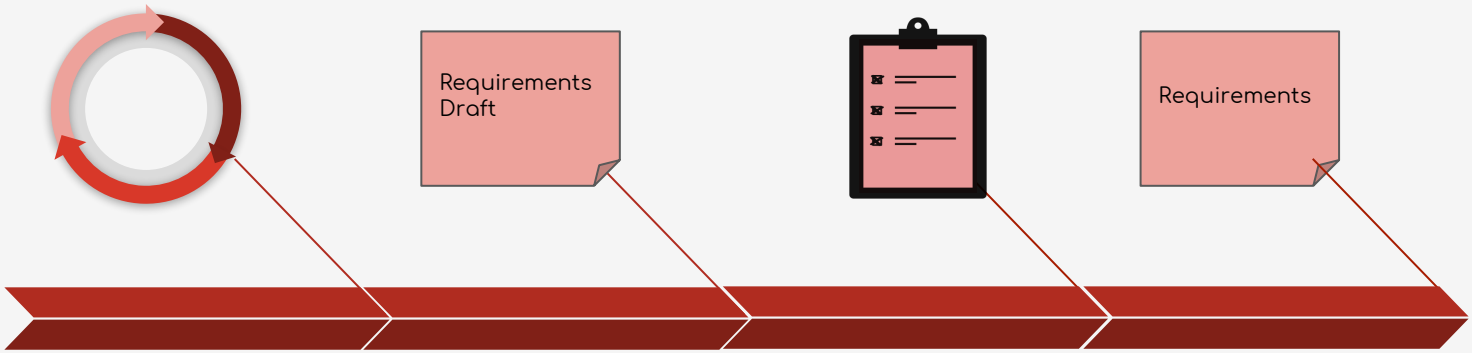
Run through concept, dev, test cycles

Internalize lessons, write initial requirements

Survey partners

Finalize requirements

Status of some example features/services…



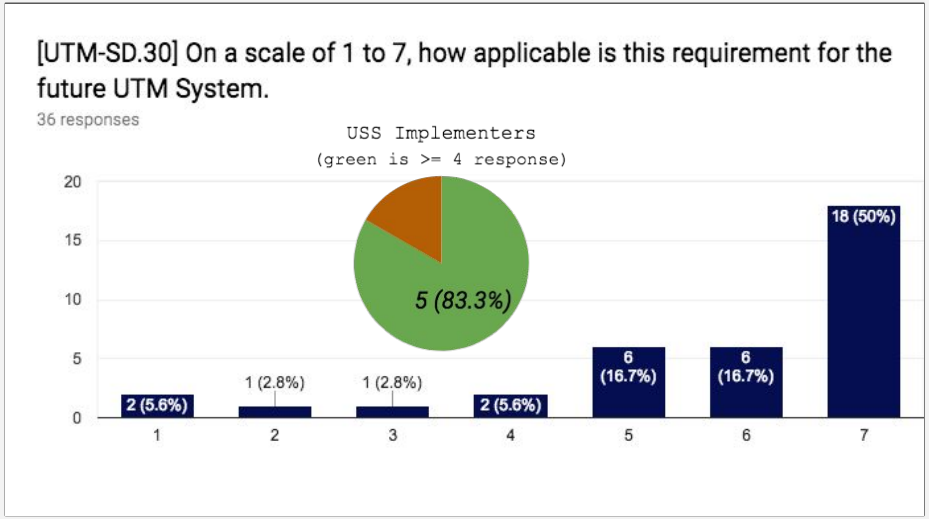
Conformance Monitoring,
Flight Notification,
Flight Awareness,
Dynamic Rerouting, etc.

USS Discovery Service,
C2 Link Requirements

Strategic Deconfliction,
Off-Nominal Situations

Example from Strategic Deconfliction Development…

[UTM-SD.30] The Prioritization scheme MUST be deterministic.

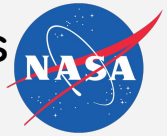


Determinism was agreeable to respondents. Comments suggested additional requirements would harden this requirement. We add that given the same inputs, the results are the deterministic. We add a requirement that the results are the same for all USSs given the same inputs. This should preemptively close requirement loopholes. Some comments suggest that there are "corner cases" that may not fit this requirement. We argue that a well designed prioritization (as defined in lower level requirements) will form a strict total ordering, though this may require certain data elements in each operation plan.

[UTM-CM.30] The Prioritization scheme MUST be deterministically calculable by each USS given the same operation data.

[UTM-CM.32] The Prioritization scheme MUST be equivalently calculable by each USS given the same operation data.

UTM Strategic Deconfliction Concept of Operations & Requirements



- A UTM Operation should be free of 4-D intersection with all other known UTM Operations prior to departure and this should be known as "Strategic Deconfliction" within UTM. The **Strategic Deconfliction** scheme:
  - **[UTM-CM.05]** MUST have the 4-D non-intersection of operations as its primary objective.
  - **[UTM-CM.10]** MUST be well-documented for the understanding of operators.
  - **[UTM-CM.12]** MUST allow for inspection of decisions by operators upon request from operators to their supporting USS.
  - **[UTM-CM.15]** MUST be supported by all USSs
  - **[UTM-CM.20]** MUST be mandated by the airspace regulator.

- Strategic Deconfliction needs a prioritization scheme for operations within UTM. The **Prioritization** scheme:
  - **[UTM-CM.25]** MUST allow for preemption of operations with lower priority by those with higher priority.
  - **[UTM-CM.30]** MUST be equivalently calculable by each USS given the same operation data.
  - **[UTM-CM.35]** MUST be efficiently calculable by each USS given the same operation data.
  - **[UTM-CM.37]** MUST be independently calculable by USSs given the same operation data.
  - **[UTM-CM.40]** SHOULD be a function of operator, operation, airspace, and vehicle parameters.

- Strategic Deconfliction needs an allowance for negotiating deconfliction of UTM operations. The **Negotiation** scheme:
  - **[UTM-CM.45]** MUST minimize direct human interaction.
  - **[UTM-CM.50]** MUST be facilitated via USSs.
  - **[UTM-CM.55]** MUST be a finite process.

- Strategic Deconfliction needs an allowance for intersecting UTM operations. **Intersecting** operators, via their USSs,:
  - **[UTM-CM.60]** MUST have preceded the decision to intersect with a negotiation process.
  - **[UTM-CM.65]** MUST each provide explicit acknowledgement to each other of the planned intersection of operation volumes when intersection is mutually decided.
  - **[UTM-CM.70]** MUST each provide details to each other on the approach to a separation provision while in intersecting operation volumes when intersection is mutually decided.

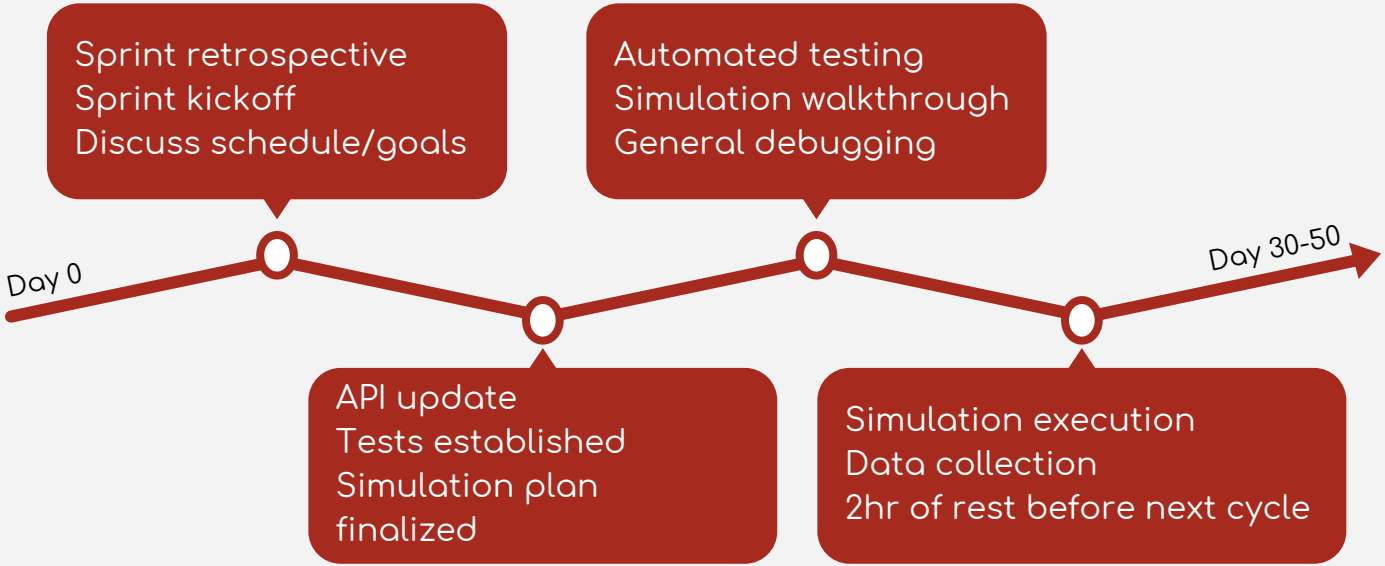
Note: Requirement labels likely to change during harmonization with other documentation. Labels to be only considered for consistency within this document.

USS Development Process for TCL4...

15-Jun-2018 to 20-Jul-2018	23-Jul-2018 To 21-Aug-2018	22-Aug-2018 To 02-Oct-2018	03-Oct-2018 To 08-Nov-2018	12-Nov-2018 To 06-Dec-2018	Late January?
Sprint 0 *Validation*	***Sprint 1*** *Security Intro*	***Sprint 2*** *Discovery*	***Sprint 3*** *Performance Authorizations*	***Sprint 4*** *FIMS, USS Handoffs, DRs and Priority Ops*	***USS Super Sim***
Enable minimal impact on-ramping of new entrants Provide initial validation of updated APIs Assure base level compliance of USSs to new API Establish baseline for future feature development and collaborative simulation	Enforce protection of endpoints per API docs Encourage use of single-scoped access_tokens Exercise new credential naming based on DNS names Test initial concept for message signing for integrity and authentication Prove concept of USS managed constraints	Implement and exercise discovery service enabling USS-USS comms Demonstrate strategic deconfliction through operation sharing Regression test Dynamic Restrictions in light of discovery Single-scoped tokens Use discovery to aid in handling off-nominal operation Develop initial off-nominal reporting	USS logging requirements for audit purposes Test Conformance Monitoring service: geo-temporal conformance Test Conformance Monitoring service in terms of PA conformance Develop and run scenario involving loss of vehicle, unplanned landing Exercise Contingency model Support post-event investigation via auditing of required logs	Test interaction between dynamic restrictions and priority operations Develop use cases for FAA requests to USSs via FIMS Implement and test a scenario for FIMS<->USS data exchange. Develop the concept of USS to USS handoff. Discuss and document concept for self-policing of USS Network (Online Compliance Monitoring Services)	High density, high tempo, long duration simulation with various elements (DRs, Rogues, etc.) introduced throughout.

Ongoing discussions regarding services: Discovery, Strat Deconflict, Conform monitoring, Flight Awareness/Notification, etc.

TCL4 General Sprint Milestones

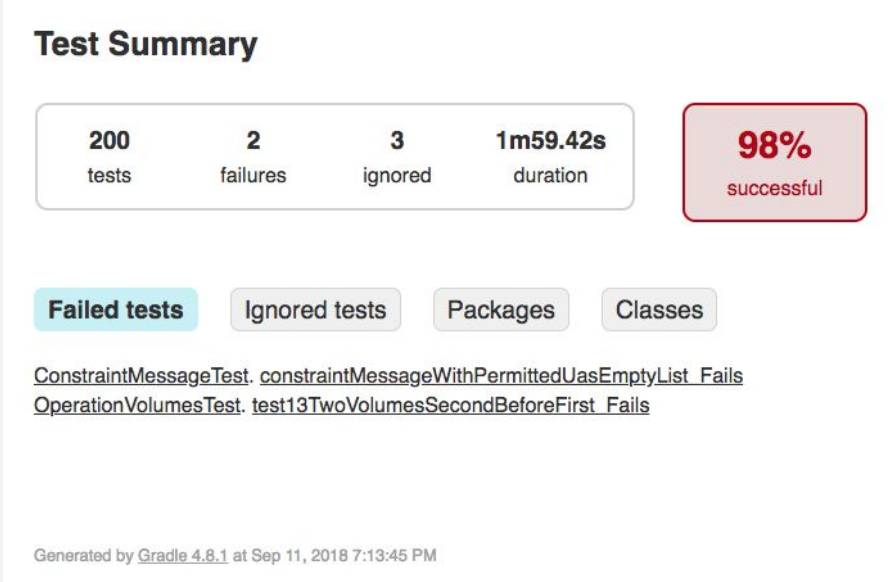


Testing Partner USSs

A test suite written using JUnit is called pointing at partner systems. A series of “unit tests” each exercising a single aspect of the API models hits their endpoints looking for the expected HTTP response.

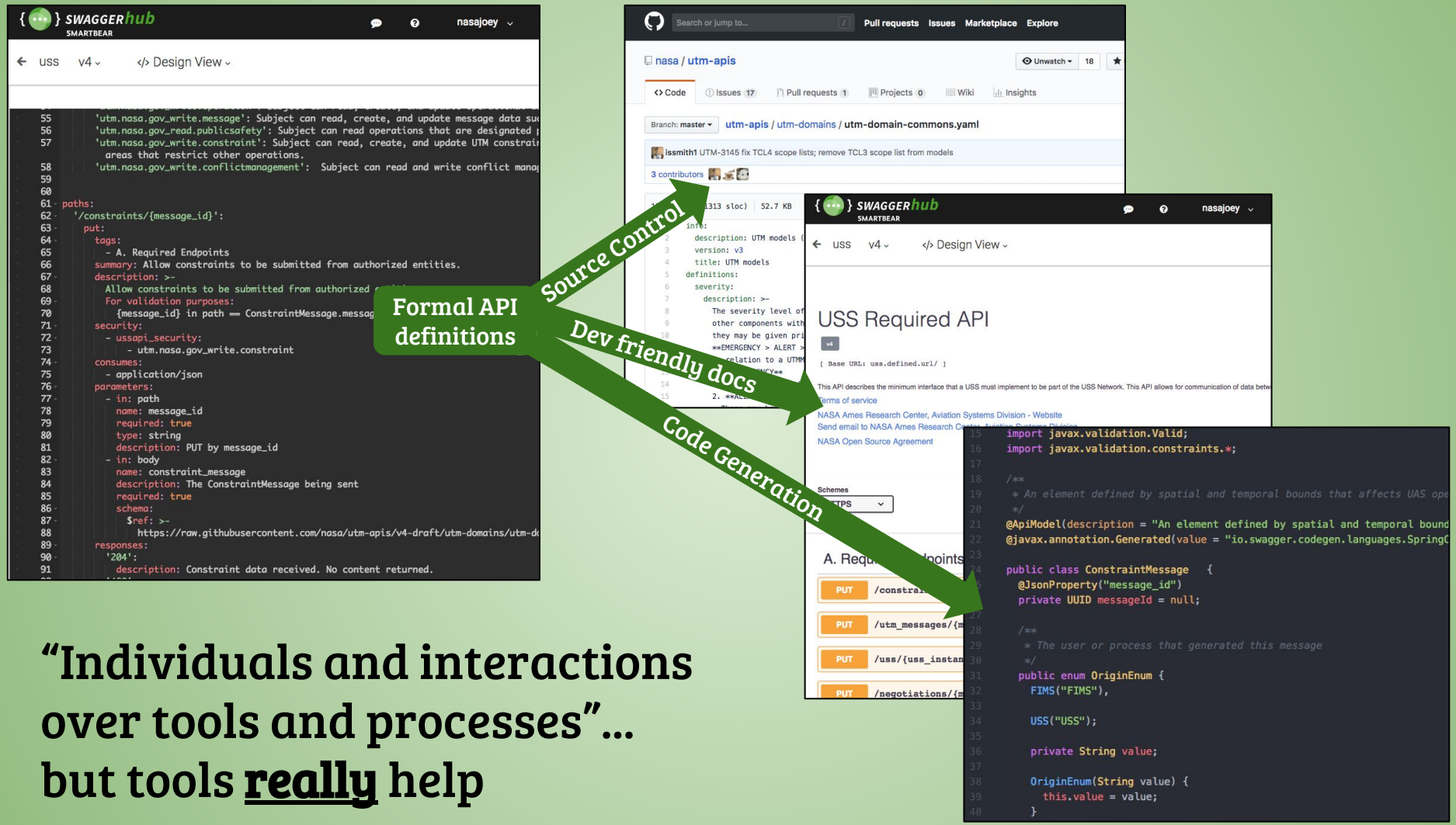
Gradle is integrated with JUnit to produce reports as as a zipped set of browser-readable files sent to partners.

Currently we run the full suite against all partners once daily. Previously we manually did it on demand. We are moving toward automated on-demand testing so partners can test their system based on their needs.



This process may form the basis of operational USS vetting and continuous compliance monitoring.

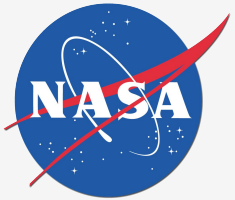
NASA UTM Technology Choices...



"Individuals and interactions over tools and processes"...
but tools **really** help

NASA USS and FIMS research platform ecosystem

Runtime		• Cloud deployment • Well-known frameworks • Geo-enabled RDBMS • Service-based architecture, API driven
CI/CD		• Code generation from APIs • Code quality and code coverage metrics • Scripted builds, infrastructure as code • Automated REST API testing
Source Control		• Access-controlled repositories • Publicly available APIs • Version controlled database schema • Formal API and model definitions
Cybersecurity		• Shift left philosophy • Secure coding practices • Threat modeling • Vetted libraries over custom code
Teaming		• Agile development • Issue and progress tracking • Daily scrums, 2-3 week sprints • Leverage external partners



UTM ConOps

UTM APIs

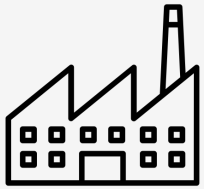
USS Specification

USS Testing Approaches

Component and Service Requirements

Testing Results and Analysis

Regulator/ANSP



Industry

Example SDOs

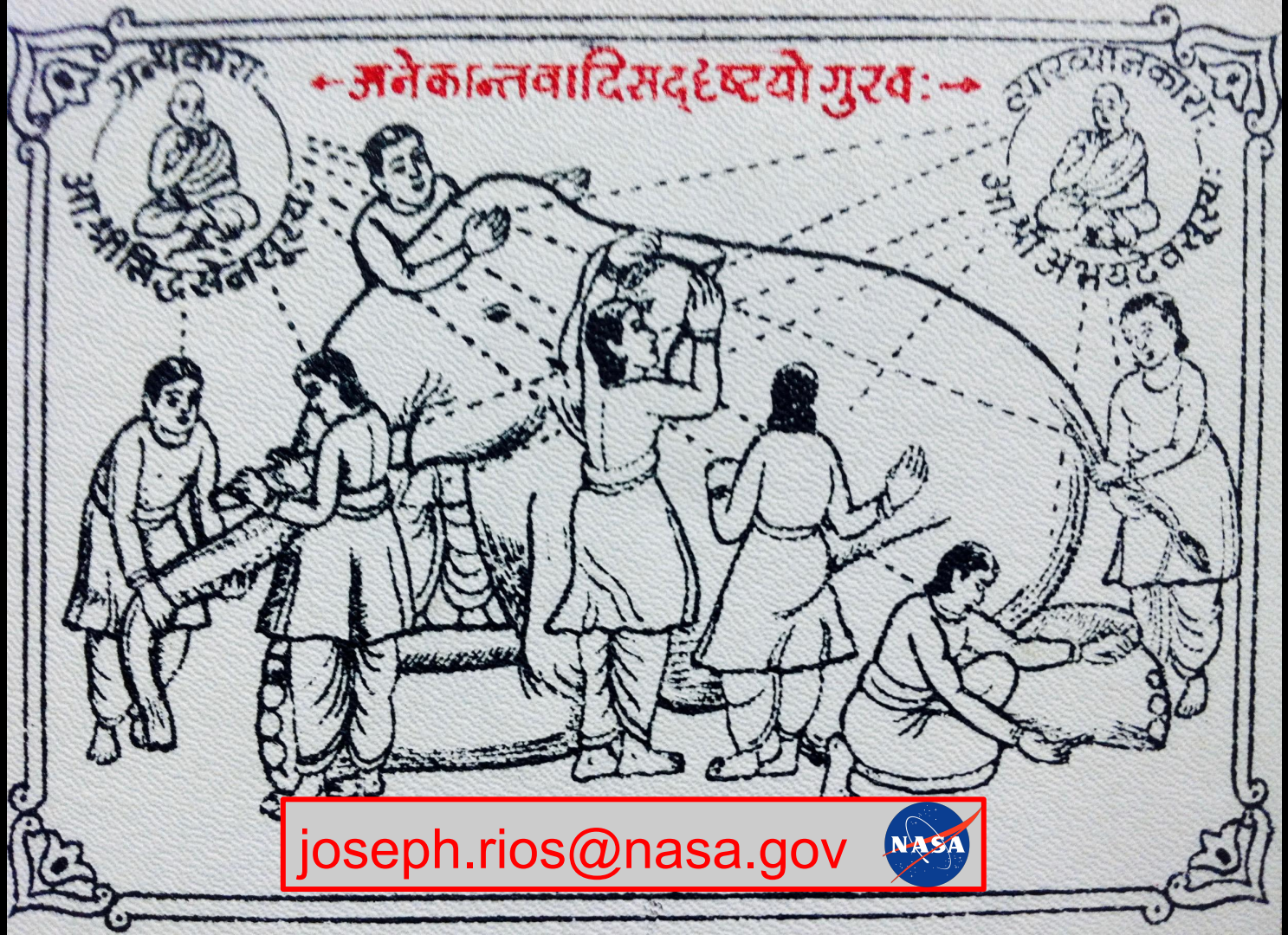
Summary

The UTM Project is successfully developing the framework and related requirements for large scale, small UAS traffic management

Processes for testing partner systems is evolving and may form the basis for future checkout requirements in an operational UTM System

Completed TCL 1, 2, and 3 Demonstrations including many testing organizations, industry, and academia partners that are crucial to validating requirements and investigating technology solutions

NASA and the FAA are closely collaborating to ensure appropriate regulatory and operational requirements are included and that technology transfers support the development of future operational systems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