Strategic Deconfliction:
System Requirements

Final Report

Joseph Rios
joseph.rios@nasa.gov
31 July 2018

Overview

This file is a combination presentation and document.
Not all “slides” are optimized for on-screen presentation.

These slides represent a revision of potential requirements for an implementation supporting Strategic Conflict Management within UTM. The full set of requirements presented here lay the groundwork for strategic deconfliction of UTM Operations from each other.

These slides DO NOT endeavor to provide generalized insight into UTM and are not intended to do so. It is assumed the audience for these slides is familiar with UTM concepts. For good introduction to UTM research, please see the initial NASA ConOps and the more recent FAA ConOps on UTM.

These are system-level requirements presented at a high level. Detailed requirements will be developed from this requirement set. Those more detailed requirements will be placed upon specific systems within UTM, such as the USS or FIMS. Architectural decisions may also be made based on this requirement set.

These slides are an important step in the formalization of UTM requirements including their validation through collaborative review.

Since we are early in this process, some of the concept of operations and the requirements are conflated, but this document should provide a clear picture of both aspects of the system description.

Approach

The requirements as listed on Slide 13 of this document were presented to the NASA UTM Project collaborators. Then a survey was developed to solicit specific responses to each requirement from the collaborators. Those responses are the driver for the final set of requirements listed in Slide 33.

Each collaborator and organization they represent brings various levels of interest and insight with regard to the UTM concept. These collaborators span a wide breadth of stakeholders within UTM: manufacturers, service providers, operators, policy specialists, researchers, etc.

Strategic conflict management

From ICAO Doc 9854, "Global Air Traffic Management Operational Concept."

2.7.10 Strategic conflict management is the first layer of conflict management and is achieved through the airspace organization and management, demand and capacity balancing and traffic synchronization components.

2.7.11 The term "strategic" is used here to mean "in advance of tactical". This recognizes that a continuum exists from the earliest planning of the user activity through to the latest avoidance of the hazard. Strategic actions will normally occur prior to departure; however, they are not limited to pre-departure, particularly in the case of longer duration flights. Changes to the trajectory (whether at the request of the user or by the service provider) will result in the selection of the best means of conflict management, which may be strategic.

2.7.12 Strategic conflict management measures aim to reduce the need to apply the second layer — separation provision — to an appropriate level as determined by the ATM system design and operation.

Important Note:
While ICAO allows for the possibility of strategic actions while airborne, this concept simplifies to assume strategic is predeparture and everything after is tactical. This aids the overall breakdown of services within UTM

Role of the Strategic Layer

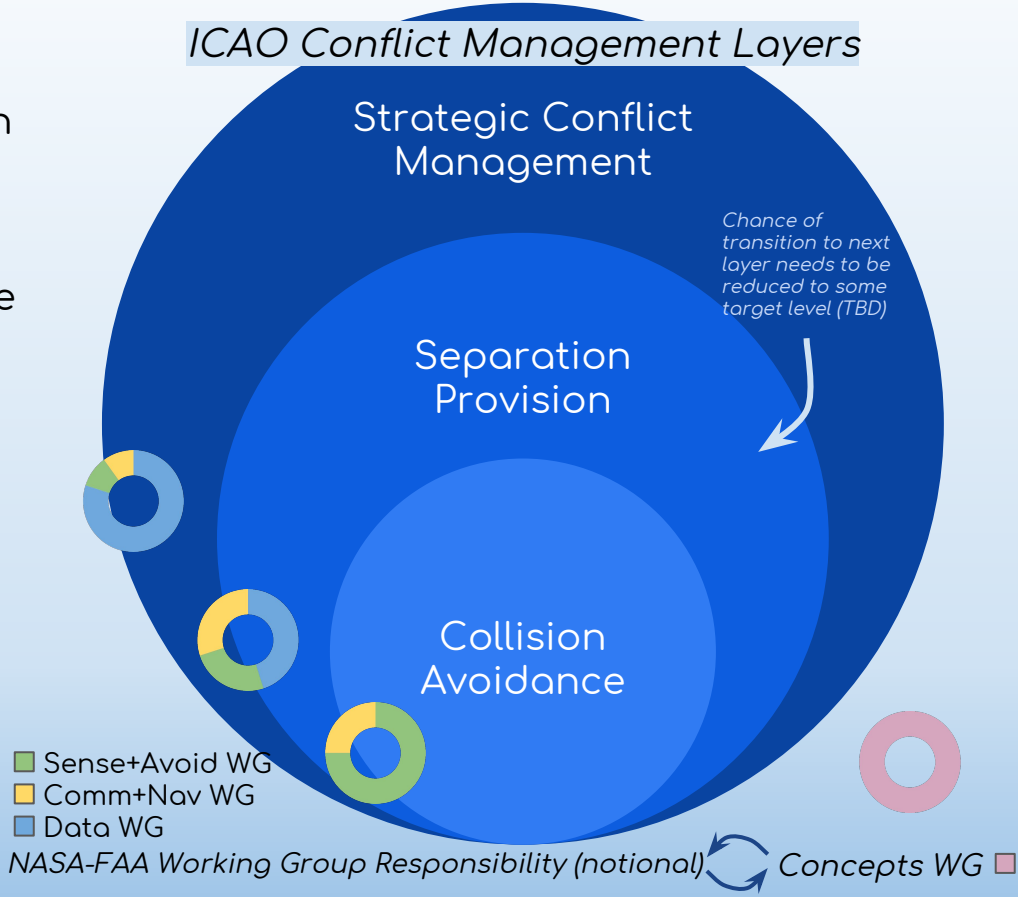
Strategic conflict management (SCM) measures reduce the need to apply separation provision and ultimately collision avoidance.

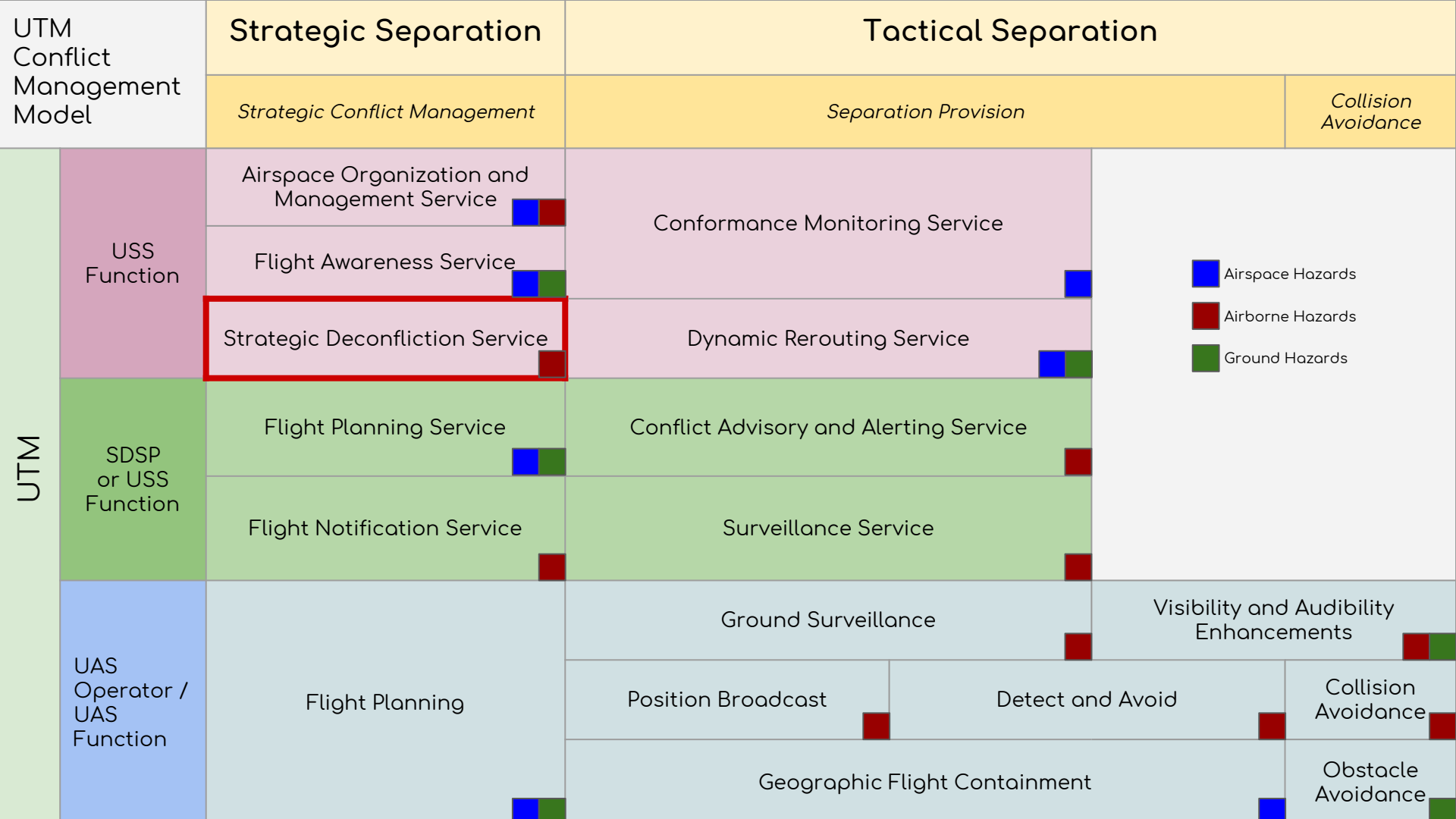
"Strategic Deconfliction" is a proposed mechanism to achieve this in UTM and is the primary topic of these slides.

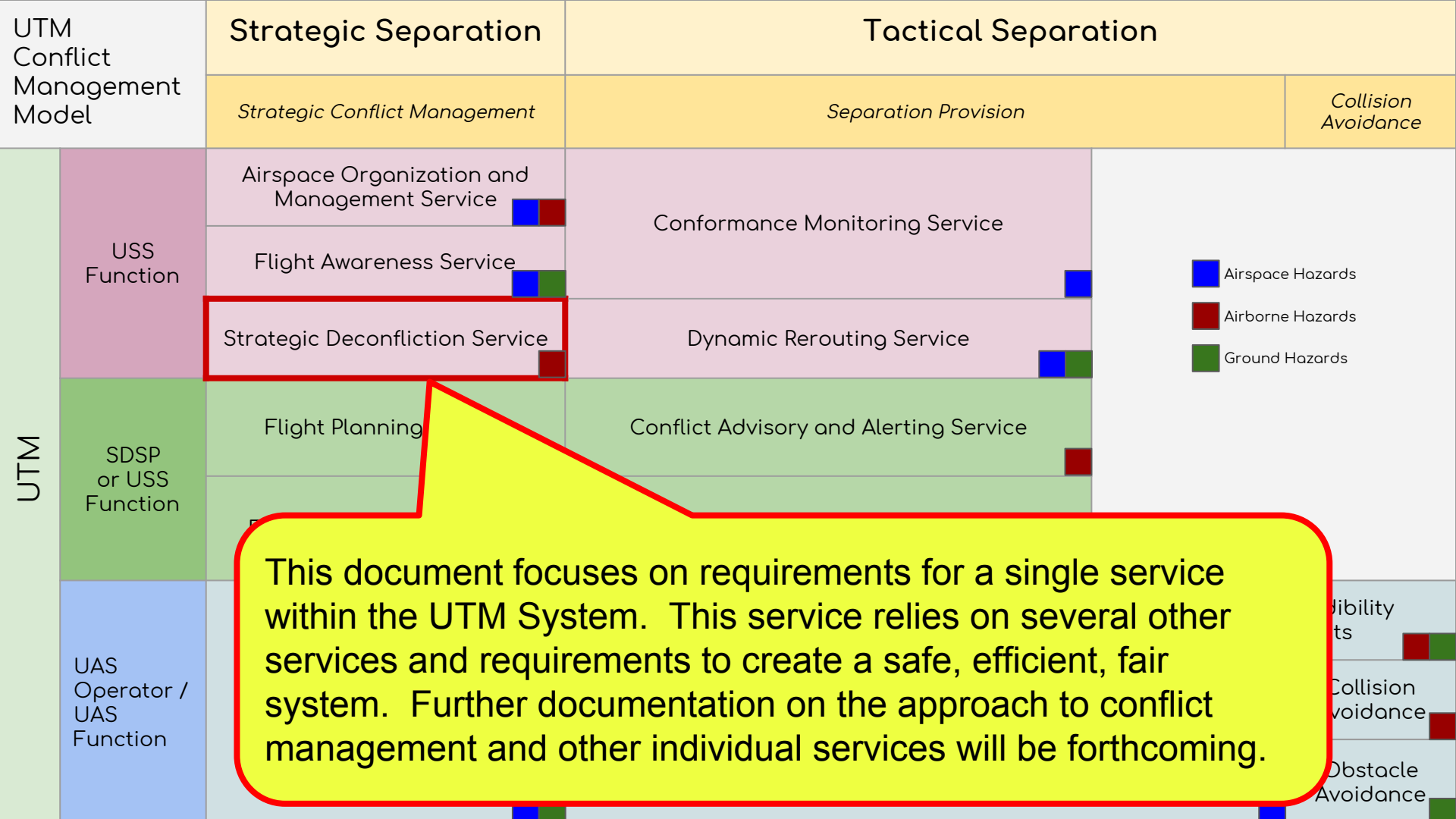
There are other aspects of SCM within UTM that are out of scope of this document.

This helps specifically with keeping cooperative UTM operations strategically separated.

SCM will never be the sole layer of conflict management and any safety case for an operation or a concept will need to address all three layers.

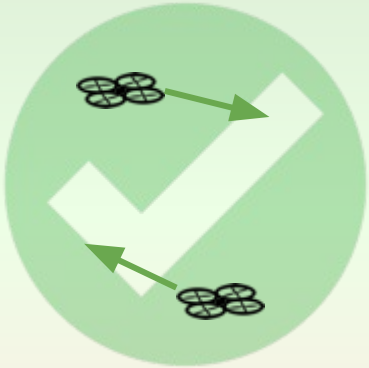



UTM Conflict Management Model
Strategic Separation
Tactical Separation
Strategic Conflict Management
Separation Provision
Collision Avoidance
UTM
USS Function
Airspace Organization and Management Service
Flight Awareness Service
Strategic Deconfliction Service
Conformance Monitoring Service
Dynamic Rerouting Service
SDSP or USS Function
Flight Planning Service
Flight Notification Service
Conflict Advisory and Alerting Service
Surveillance Service
UAS Operator / UAS Function
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



This document focuses on requirements for a single service within the UTM System. This service relies on several other services and requirements to create a safe, efficient, fair system. Further documentation on the approach to conflict management and other individual services will be forthcoming.

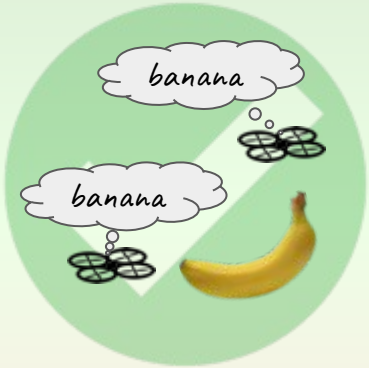
UTM five core operating principles



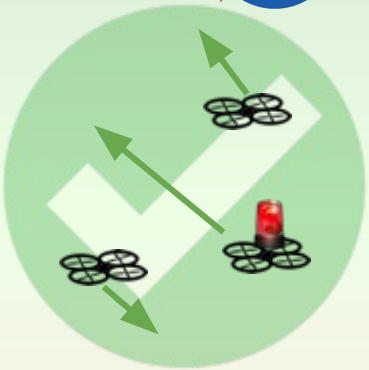
UAS don’t hit each other

UAS don’t hit manned traffic

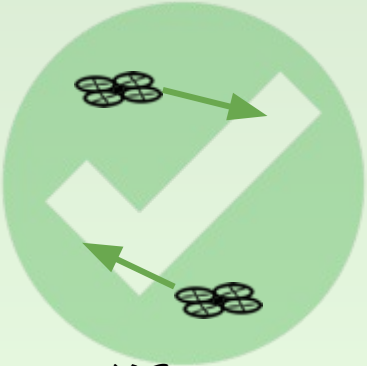
Actors are identifiable



Common situational awareness

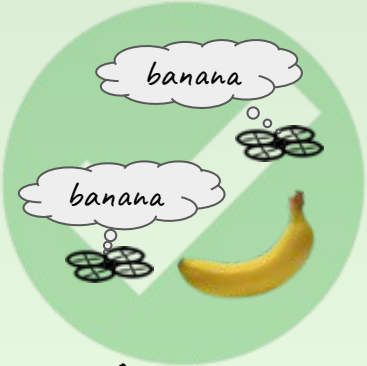


Public safety ops have priority

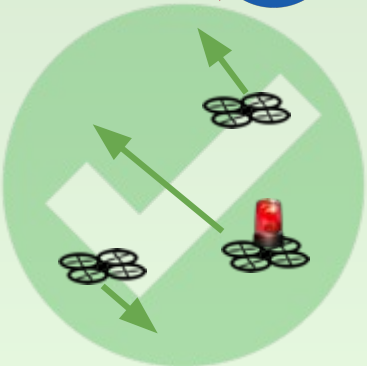


UAS AVOID EACH OTHER

- 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.
- There must be a prioritization scheme for operations within UTM.
- A UTM Operator must have a facility to negotiate deconfliction of operations with other UTM Operators when that Operator has a lower priority operation.
- There needs to be a capability to allow for intersecting operations.



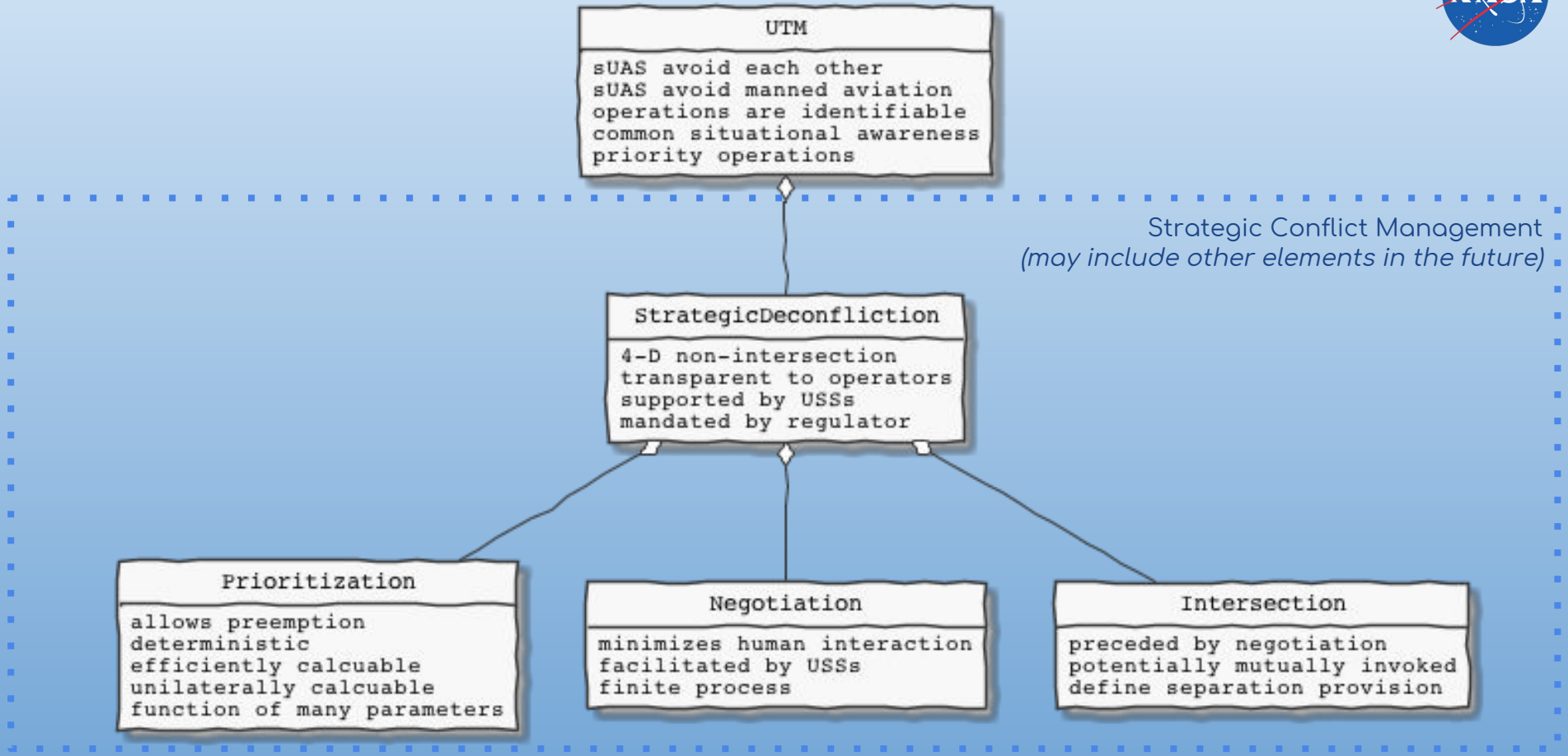
OPERATORS HAVE COMMON AWARENESS



ACCESS FOR PRIORITY OPS

This requirement set directly supports three of the five core operating principles as stated in the [UTM Concept of Operations](#).

Strategic Deconfliction Concept v20180604



Requirements Terms

We rely on the IETF definitions for requirement terms within this document.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

Key definitions used in this document:

MUST
This word, or the terms "REQUIRED" or "SHALL", mean that the definition is an absolute requirement of the specification.

SHOULD
This word, or the adjective "RECOMMENDED", mean that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.

Note on “Strategic”

There were many comments (on individual requirements and in summary) that related to the limitation of these requirements to pre-departure operations only. The distinction of “strategic” to imply pre-departure operations is aligned with other organizations and aids in decomposing the services within UTM with clear boundaries.

We understand the perspective that the requirements and concepts discussed in the Strategic Deconfliction slides seemed equally applicable to en route traffic. To be more specific, we see the applicability of these requirements to Dynamic Rerouting, which is a Separation Provision service within UTM. This relationship will be manifest in the form of lower level requirements for both Strategic Deconfliction and Dynamic Rerouting that trace up to the requirements in these slides.

To better reflect this fact, these requirements are renamed to UTM-CM-xx with “CM” implying “Conflict Management” of which SD and DR are a part.

UTM Strategic Deconfliction Concept of Operations & Requirements

Requirements as presented in the survey. Update based on the survey presented on Slide 33.

- 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-SD.05]** MUST have the 4-D non-intersection of operation plans as its primary objective.
  - **[UTM-SD.10]** MUST be transparent to operators.
  - **[UTM-SD.15]** MUST be supported by all USSs
  - **[UTM-SD.20]** MUST be mandated by the airspace regulator.

- Strategic Deconfliction needs a prioritization scheme for operations within UTM. The **Prioritization** scheme:
  - **[UTM-SD.25]** MUST allow for preemption of operations with lower priority by those with higher priority
  - **[UTM-SD.30]** MUST be deterministic.
  - **[UTM-SD.35]** MUST be efficiently calculable by USSs.
  - **[UTM-SD.37]** MUST be unilaterally calculable by USSs.
  - **[UTM-SD.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-SD.45]** SHOULD minimize or eliminate direct human interaction.
  - **[UTM-SD.50]** MUST be facilitated via USSs.
  - **[UTM-SD.55]** MUST be a finite process.

- Strategic Deconfliction needs an allowance for intersecting UTM operations. **Intersecting** operators, via their USSs,:
  - **[UTM-SD.60]** MUST have preceded the decision to intersect with a negotiation process.
  - **[UTM-SD.65]** MUST <u>each</u> provide explicit acknowledgement to each other of the planned intersection of operation volumes when intersection is mutually decided.
  - **[UTM-SD.70]** MUST <u>each</u> provide details to each other on the approach to a separation provision while in intersection operation volumes when intersection is mutually decided.
  - **[UTM-SD.75]** MUST provide acknowledgement of responsibility and risk related to operation volume intersection whenever intersection is unilaterally decided by that operator.

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

Survey Results Overview

This document will be considered the final report for the survey results. **The data and analysis should be considered preliminary and is only provided to give insight to the process as early as possible.** The requirements themselves will be cataloged with other UTM System requirements and presented by NASA to the FAA as part of our RTT process some time in the future.

Some caveats for the graphs:

- Did not exclude any respondents in these results.
- There are three orgs represented with two respondents
- There is one org with three respondents
- One of the orgs with two respondents is NASA, though they are from non-UTM Project personnel

We provide a single breakout of a key group: USS Implementers. Each of the six USS implementers were represented by a single respondent. NASA did not verify that the respondent was authorized to speak on behalf of their organization, but NASA was familiar with each respondent and felt their responses were indicative of their organization.

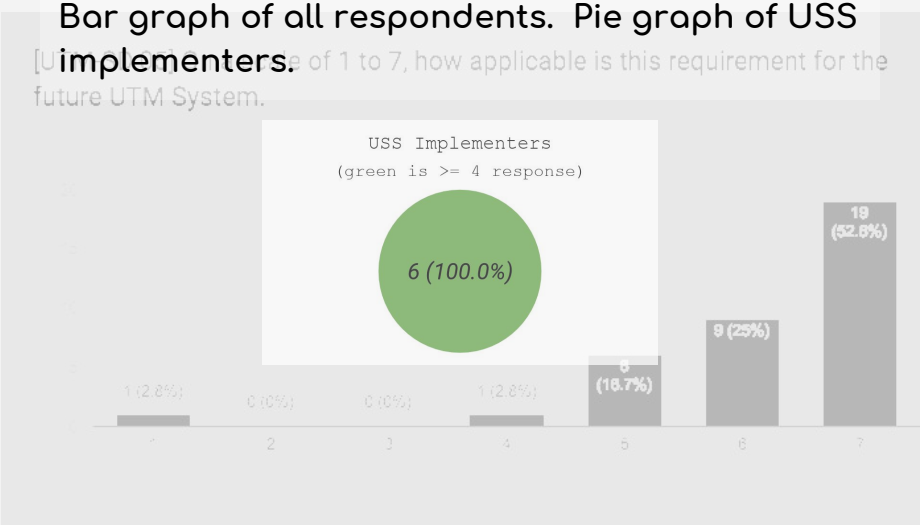
NASA feels that on the issues related to the strategic time horizon as well as other aspects of the future UTM System, that those that have built USSs have key insights. In addition, all of these USS Implementers have had operations flown against their systems in NASA flight tests. The breakout is provided as a pie graph superimposed on the bar graph. The green area captures the "positive" responses with a value of 4 or greater.

Results slide example

The next slide is an example of how the results are presented on a per-requirement basis in the slides that follow.

[ORIGINAL REQUIREMENT LABEL] As-presented requirement Text.

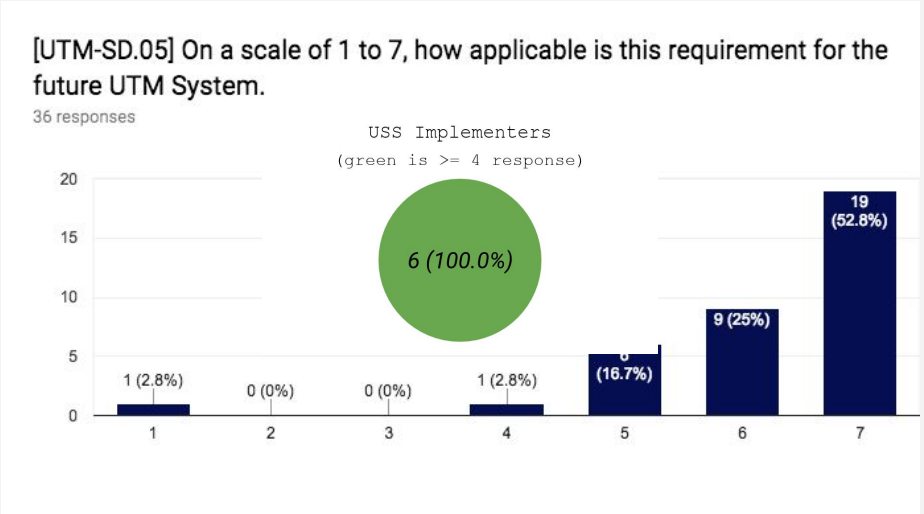
Bar graph of all respondents. Pie graph of USS implementers.



Discussion about the results and how they affect the requirement outcome.

[FINAL REQUIREMENT LABEL] Final requirement text.

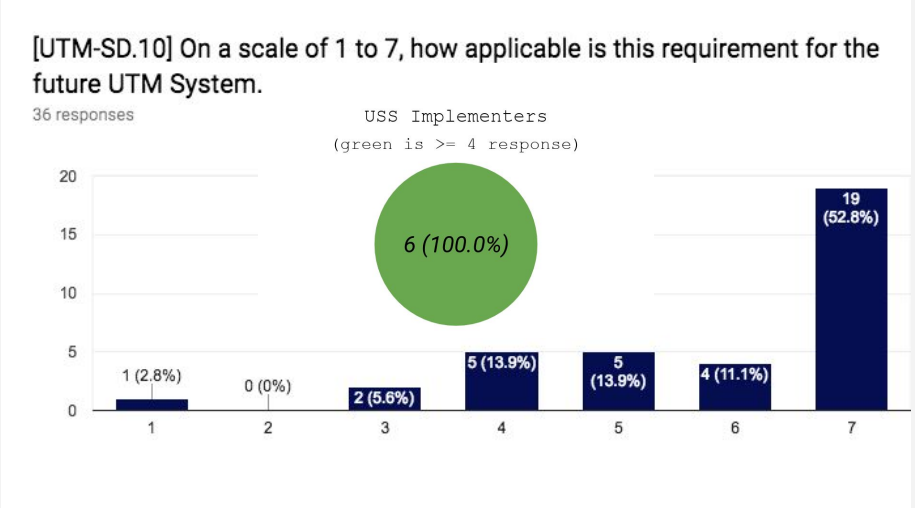
[UTM-SD.05] The Strategic Deconfliction scheme MUST have the 4-D non-intersection of operation plans as its primary objective.



The focus on "strategic" was complicated for respondents. The requirements seem to apply just as well to active operations. The main response to this is that there will be parallel requirements for Dynamic Rerouting to address this concern. We keep them separate to allow more flexibility in application, but the requirements will look very similar. Also concerns about prioritization here (public safety priority, efficient planning priority, etc.). We feel these should be captured in the prioritization requirements and will be more concrete at lower requirement levels. Efficient planning will be a separate set of requirements developed in conjunction with the C+N working group. Reword to remove "plans" from requirement language.

[UTM-CM.05] The Strategic Deconfliction scheme MUST have the 4-D non-intersection of operations as its primary objective.

[UTM-SD.10] The Strategic Deconfliction scheme MUST be transparent to operators.

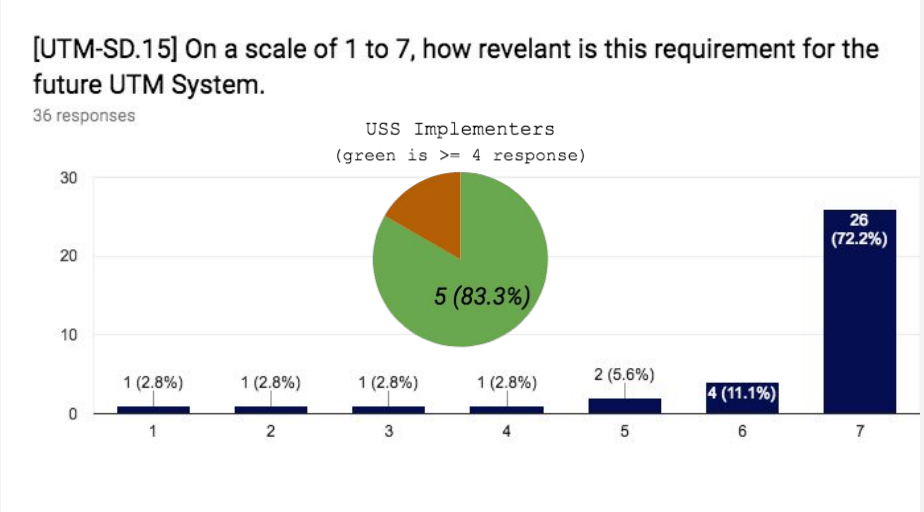


The lack of a definition for "transparent" was apparent. The original intent was to ensure that operators were aware that SD existed in the UTM System and was executed on their behalf by the USS. The operator, as a result of this requirement, would have access to how the process works and potentially the reason for a given SD decision provided to them by a USS. This was the idea of "transparency" in this requirement. Based on the comments, we think this addresses some concerns. Given the determinism other requirements, the goal would be confidence of the operator that the system is performing "fairly" on their behalf.

[UTM-CM.10] The Strategic Deconfliction scheme MUST be well-documented for the understanding of operators.

[UTM-CM.12] The Strategic Deconfliction scheme MUST allow for inspection of decisions by operators upon request from operators to their supporting USS.

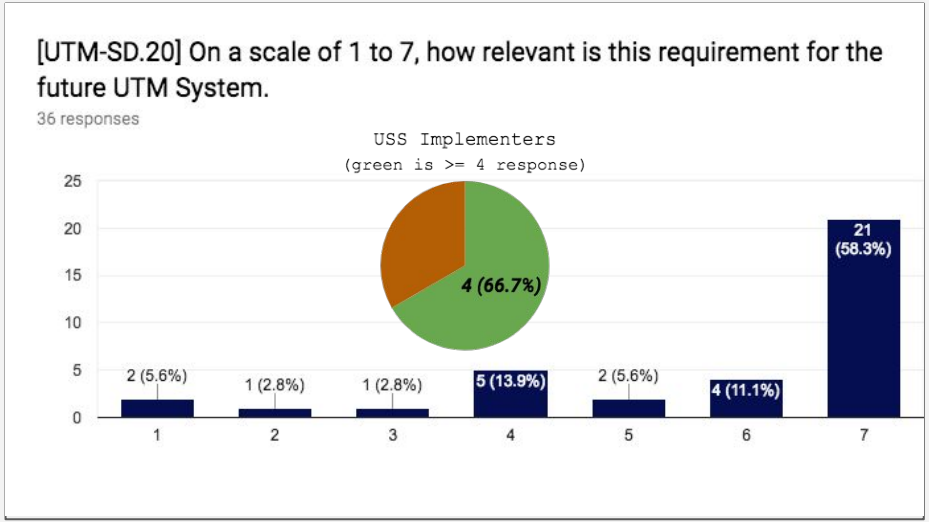
[UTM-SD.15] The Strategic Deconfliction scheme MUST be supported by all USSs.



This requirement had wide acceptance. Some comments hinted at the need for more specificity in the requirement. We think this will be provided in the lower level requirements that trace up to this one.

[UTM-CM.15] The Strategic Deconfliction scheme MUST be supported by all USSs.

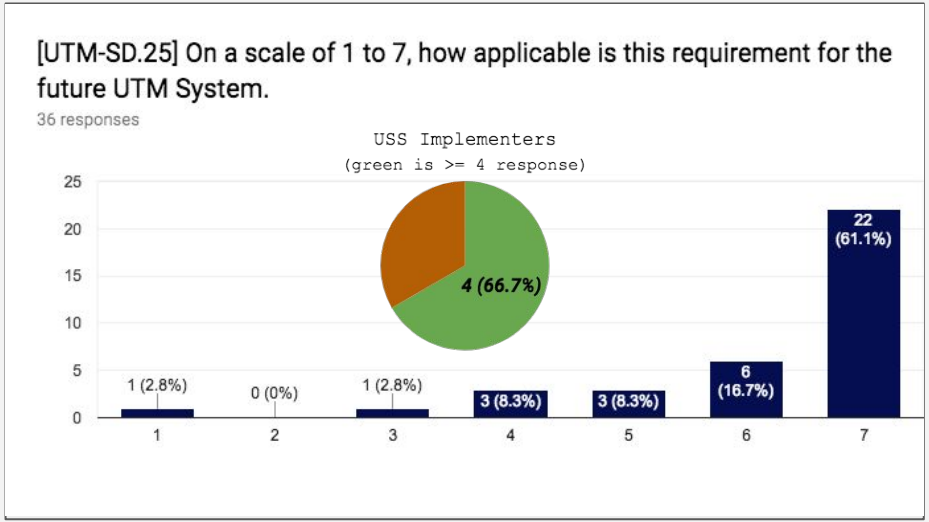
[UTM-SD.20] The Strategic Deconfliction scheme MUST be mandated by the airspace regulator.



There was some common comments related to WHICH SD approach would be mandated. We believe this is nailed down through the lower level requirements. We agree that the "right" SD approach is what is to be mandated under this requirement. Another common comment thread involved whether the airspace regulator is the right entity, but we think this sentiment may be more driven by not having the regulator be in complete control of the SD approach. We agree that stakeholders and industry will be key in helping choose, prove out, and maintain the SD approach. That sentiment does not seem to detract from the requirement itself.

[UTM-CM.20] The Strategic Deconfliction scheme MUST be mandated by the airspace regulator.

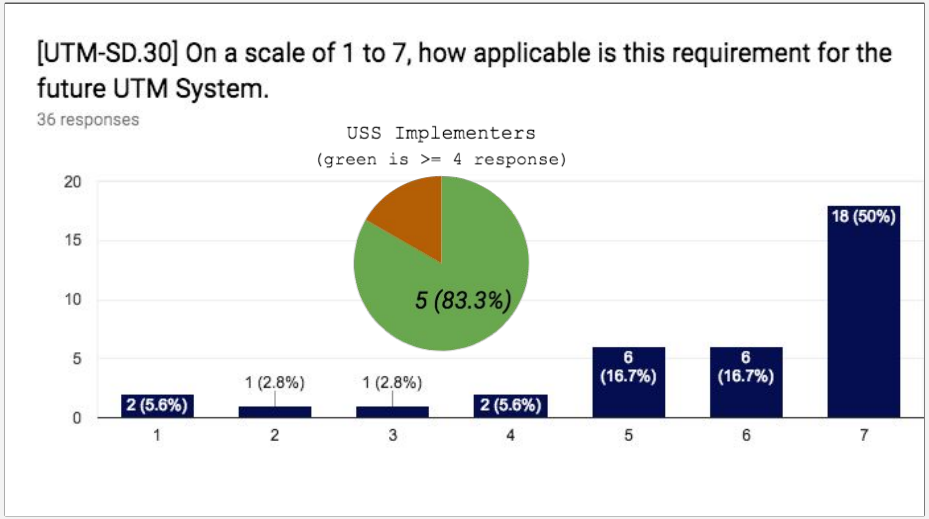
[UTM-SD.25] The Prioritization scheme MUST allow for preemption of operations with lower priority by those with higher priority.



The general sense of the comments revolved around wondering about the correct prioritization scheme. We agree this is important and will be better addressed by lower level requirements. This requirement points directly to the core principle that there is allowance in the system for priority operations. Other key comments pointed to the need to bound and monitor priority announcements such that they do not become abused resulting in denying access to airspace to nominal operations. We agree and think this can and will be handled by lower level requirements.

[UTM-CM.25] The Prioritization scheme MUST allow for preemption of operations with lower priority by those with higher priority.

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

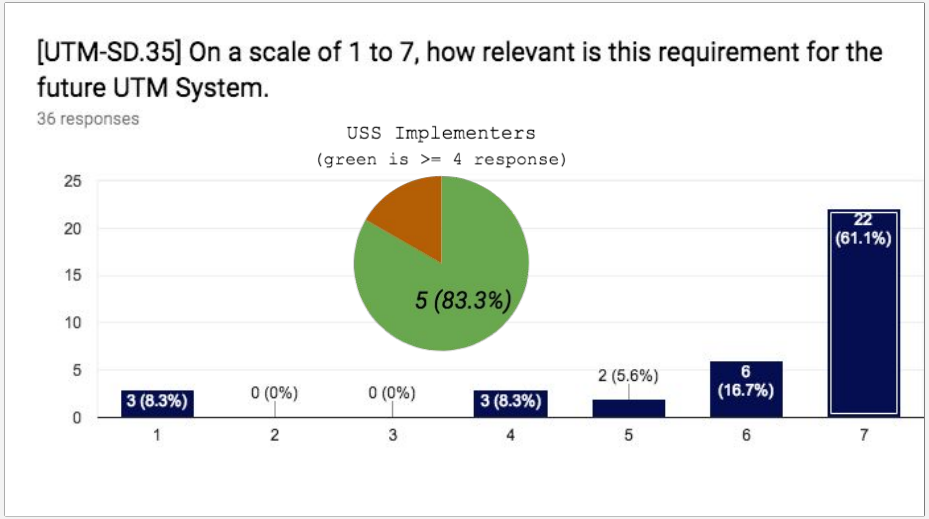


Determinism was agreeable to respondents. Comments suggested additional requirements would harden this requirement. We add that given the same inputs, the results are the deterministic. We add a requirement that the results are the same for all USSs given the same inputs. This should preemptively close 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.

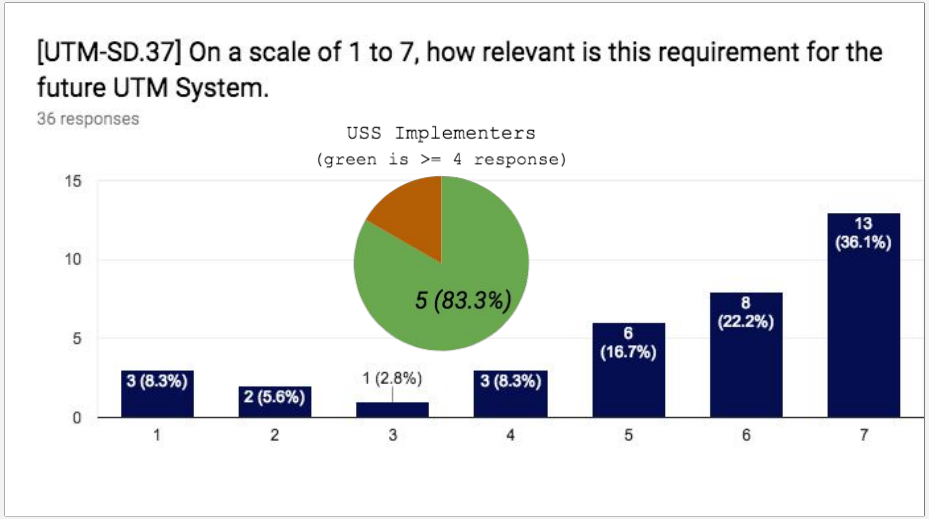
[UTM-SD.35] The Prioritization scheme MUST be efficiently calculable by USSs.



This was generally well-accepted. Some comments on how we would measure or define "efficiently" in this requirement. This is valid to ask. We would defer such metrics for lower level requirements. These will likely take the form of being proven calculable within some time on some specific hardware as a benchmark. Then implementations would have to prove results for a test set of data that beat this benchmark. Note that these results would not take into consideration network latency. Service level agreements on elements such as that would be in a separate set of requirements unrelated directly to SD. We add some text to the requirement to align with new .30 and .32 requirement wording.

[UTM-CM.35] The Prioritization scheme MUST be efficiently calculable by each USS given the same operation data.

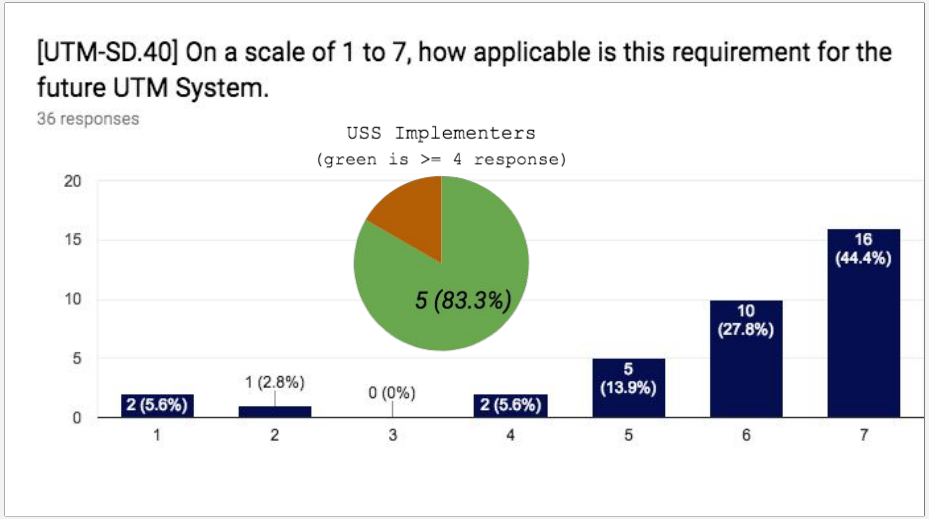
[UTM-SD.37] The Prioritization scheme MUST be unilaterally calculable by USSs.



This requirement had the lowest number of "7's" recorded. Based on the comments, this may have been due to some ambiguity in the wording. We tried to address this by swapping in "independently" for "unilaterally" and added the same "given…" statement as in .30, .32, and .35 above. We think this will address a good number of the supplied comments.

[UTM-CM.37] The Prioritization scheme MUST be independently calculable by USSs given the same operation data.

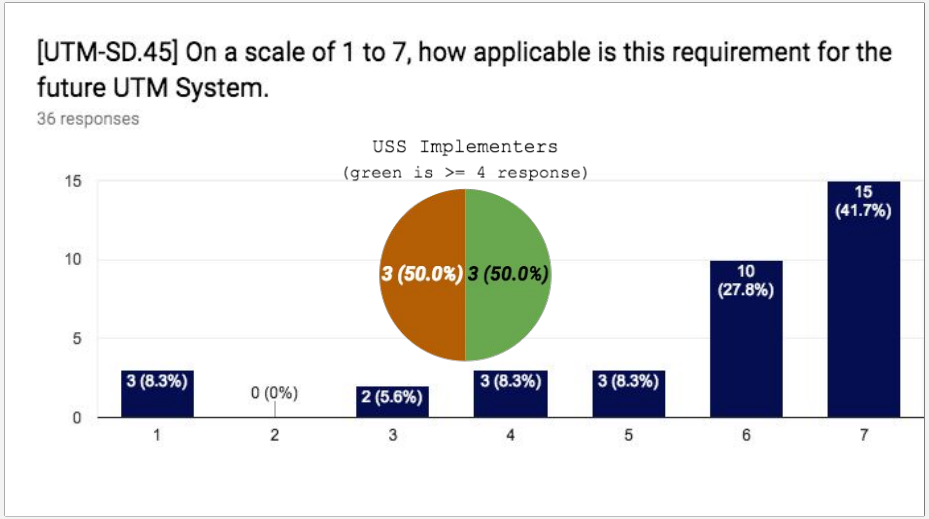
[UTM-SD.40] The Prioritization scheme SHOULD be a function of operator, operation, airspace, and vehicle parameters.



3 of 15 respondents who left comments wanted this to be a MUST statement. Some respondents were concerned that there would be more parameters in the future, another felt it should ONLY be based on the operation and no other parameters. As lower level requirements get developed, this recommendation will become more clear. This might evolve into a MUST statement if the lower level requirements are written clearly enough. The concern making this a MUST statement is that it might imply that all prioritization would require consideration of all elements, when only one matters. Leaving this one as-is for now with the understanding/hope that concerns are addressed by lower level requirements.

[UTM-CM.40] The Prioritization scheme SHOULD be a function of operator, operation, airspace, and vehicle parameters.

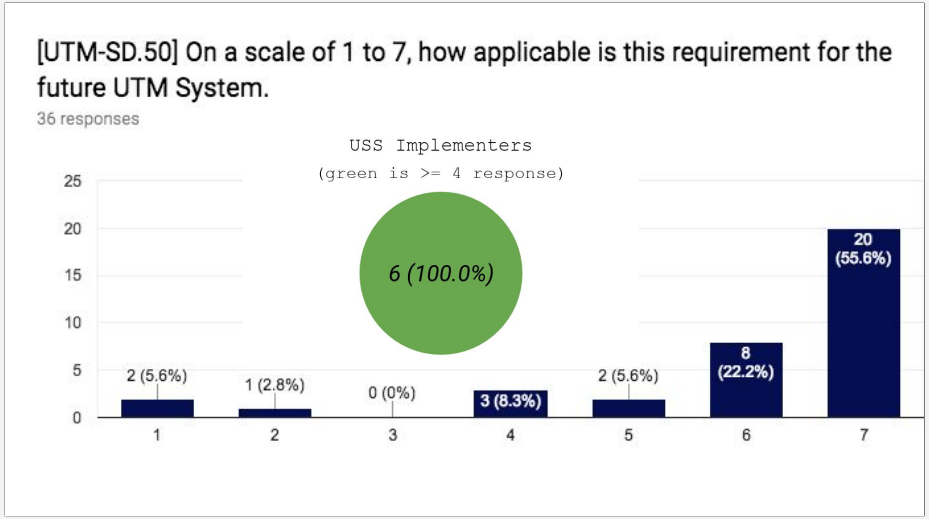
[UTM-SD.45] The Negotiation scheme SHOULD minimize or eliminate direct human interaction.



There were a number of strong opinions in the comments. We think there was some individual interpretation of this recommendation as written. There is not an intention or ability for UTM to be fully automated in all aspect upon initial implementation of capabilities. We agree there will be special cases were humans need to be involved and this need may persist long into UTMs existence. The goal still needs to be minimization of human interaction for these operations to scale and be efficient. We are altering the language to make it a MUST statement and removing the "eliminate" clause. The goal is the minimize... eventually that may mean eliminating (for the most part) human interaction in negotiations.

[UTM-CM.45] The Negotiation scheme MUST minimize direct human interaction.

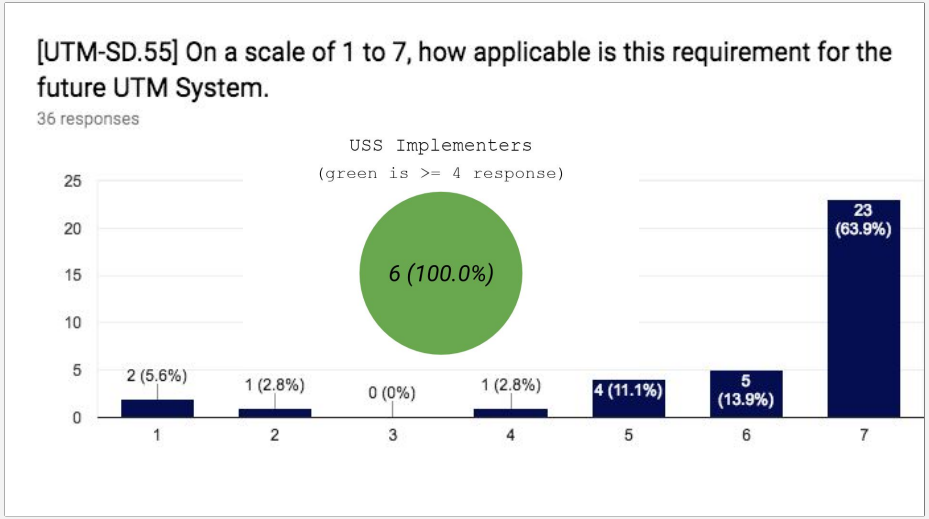
[UTM-SD.50] The Negotiation scheme MUST be facilitated via USSs.



This was fairly well-accepted and is remaining as-is for now. There were some comments (at least 3) as to allowing negotiation by other means. This is not disallowed due to this requirement. This requirement pertains to THE Negotiation scheme as defined and required for USSs to implement. Operators may still negotiate in traditional or other means, there just will not be a requirement to do so within UTM.

[UTM-CM.50] The Negotiation scheme MUST be facilitated via USSs.

[UTM-SD.55] The Negotiation scheme MUST be a finite process.



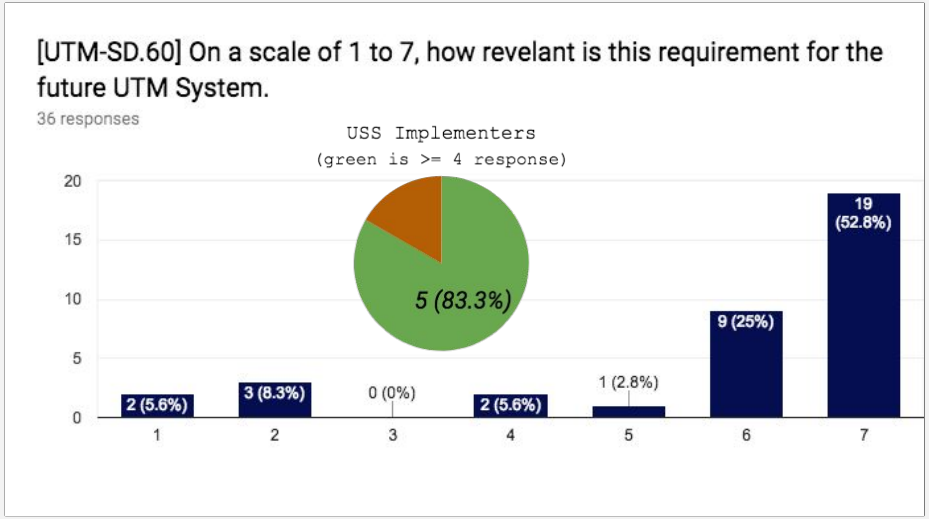
The goal of this requirement is to ensure that negotiations between two USSs on behalf of their operators do not continue indefinitely and that a clear "end" is guaranteed by the automated negotiation process.

The comments made it clear that an additional requirement should be written that helps scope what the negotiation scheme is intended to accomplish. This additional requirement will be in the final report.

This requirement remains as-is with the assumption of a future supporting requirement scoping negotiation more clearly.

[UTM-CM.55] The Negotiation scheme MUST be a finite process.

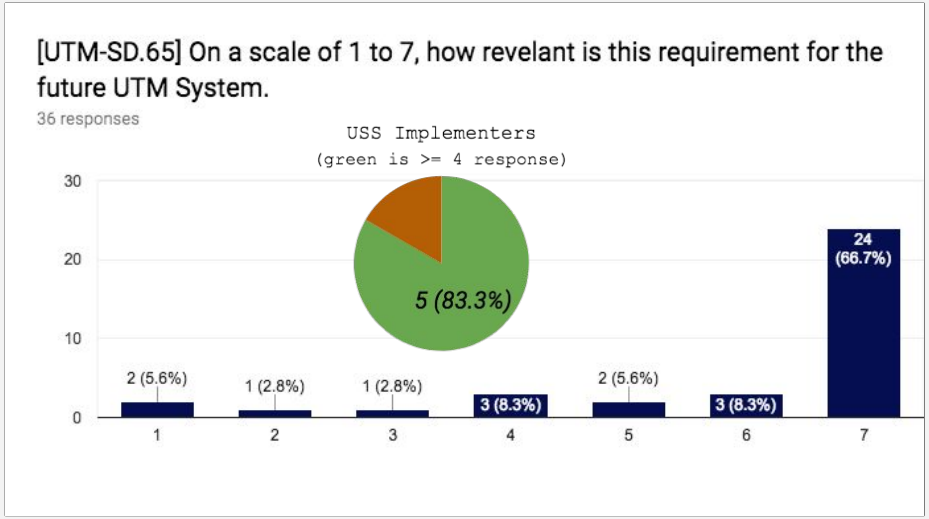
[UTM-SD.60] Intersecting operators, via their USSs, MUST have preceded the decision to intersect with a negotiation process.



There was some concern as to why we want a provision for intersecting operations at all. This is a reasonable question. Through discussions with stakeholders, there may be scenarios where intersections are reasonable, assuming that operators are aware of and assume the risks. This avenue for potential intersecting operation volumes also may help avoid the impression that all of the airspace can be "reserved" or otherwise denied for access by operators. The primary objective, as stated in .05 is always the 4D deconfliction of operations. As a backup, we create the potential for intersections under the appropriate conditions and assumption of risk. It may be that efficiency of planning and vehicle capabilities eventually make intersections moot.

[UTM-CM.60] Intersecting operators, via their USSs, MUST have preceded the decision to intersect with a negotiation process.

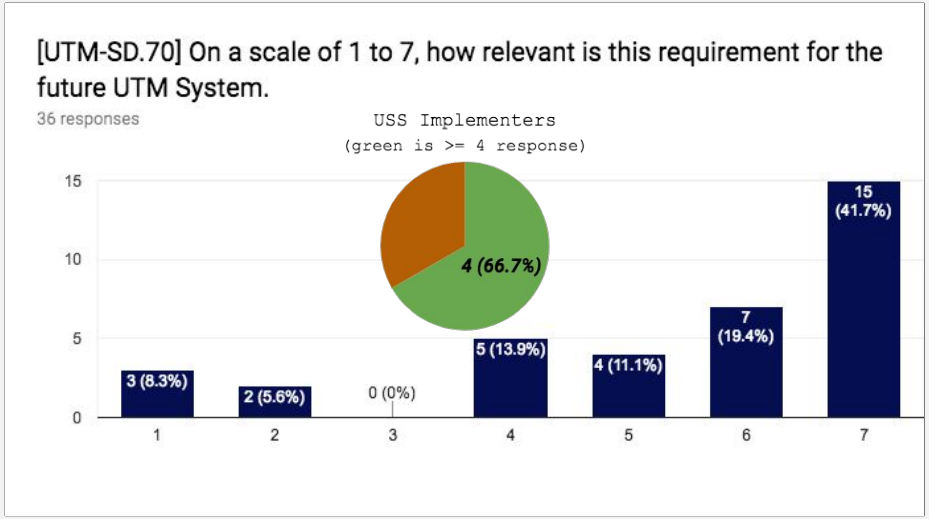
[UTM-SD.65] Intersecting operators, via their USSs, MUST each provide explicit acknowledgement to each other of the planned intersection of operation volumes when intersection is mutually decided.



This had broad acceptance and is left as-is. It was noted in the comments that this requirement really needs .60 to ensure that operators are completely aware of other operations and have gone through the other steps to try to eliminate this intersection before agreeing to intersect.

[UTM-CM.65] Intersecting operators, via their USSs, MUST each provide explicit acknowledgement to each other of the planned intersection of operation volumes when intersection is mutually decided.

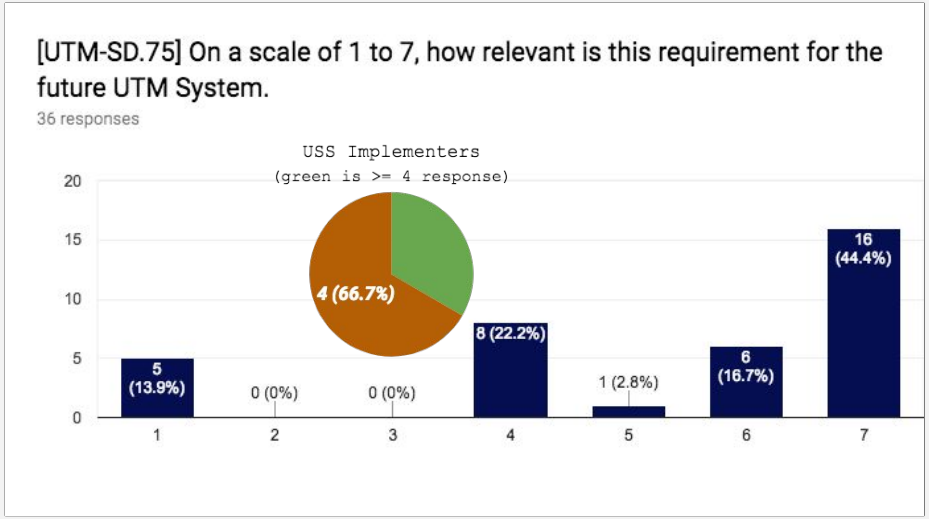
[UTM-SD.70] Intersecting operators, via their USSs, MUST each provide details to each other on the approach to a separation provision while in intersection operation volumes when intersection is mutually decided.



Several comments on this requirement mention Detect and Avoid (DAA) and efficient operation planning and rules of the road as being requirements. We agree. DAA would likely be a component of the separation provision. Efficient planning will be enforced in multiple ways in the operational UTM. For example a simple forcing function is to minimize your chances of intersecting with anyone and to reward efficient plans in "breaking ties" for operations that are intersecting. Rules of the road for sUAS are potentially overly simple or overly complex, but they will likely be part of the future system. These (DAA, planning, rules of road) are separate and potentially lower-level requirements that are envisioned for the UTM System. Just a grammar change (intersection -> intersecting).

[UTM-CM.70] Intersecting operators, via their USSs, MUST each provide details to each other on the approach to a separation provision while in intersecting operation volumes when intersection is mutually decided.

[UTM-SD.75] Intersecting operators, via their USSs, MUST provide acknowledgement of responsibility and risk related to operation volume intersection whenever intersection is unilaterally decided by that operator.



There were strong opinions in opposition to this requirement, despite a majority of "7's". This response had the highest number of responses less than 5 (13 total, while the average number of responses less than 5 was just 6.8). It also had the highest number of "1's" in the survey at 5.

Many on NASA UTM would also not want unilateral decisions to intersect, given the opportunity to encourage efficient planning and negotiation.

For now, we remove this requirement pending further developments or discussions. This eliminates the possibility of active, unilateral decisions for one UTM operation to intersect with another known/ announced UTM operation. In the future, this requirement will likely need re-visitation.

~~[UTM-CM.75] Intersecting operators, via their USSs, MUST provide acknowledgement of responsibility and risk related to operation volume intersection whenever intersection is unilaterally decided by that operator.~~

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 <u>each</u> provide explicit acknowledgement to each other of the planned intersection of operation volumes when intersection is mutually decided.
  - **[UTM-CM.70]** MUST <u>each</u> 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.

Summary

This document provides an overview of requirements developed through a survey-based approach with stakeholders. These potential requirements for a future operational system help define a Strategic Deconfliction Service for UTM. From the NASA UTM Project perspective, Strategic Deconfliction is a key layer in the conflict management model for UTM and a core service that will be provided by all USSs in the future UTM System.

The requirements presented have undergone an initial validation step through survey with stakeholders working with NASA on UTM development.

These requirements will aid in the design of Strategic Deconfliction and will be part of a larger set of requirements that define the UTM System, as proposed by the NASA UTM Project.

joseph.rios@nasa.gov