National Aeronautics and Space Administration

Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

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RTCA SC203 Plenary Session
WG3 Sense and Avoid
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Presentation Outline

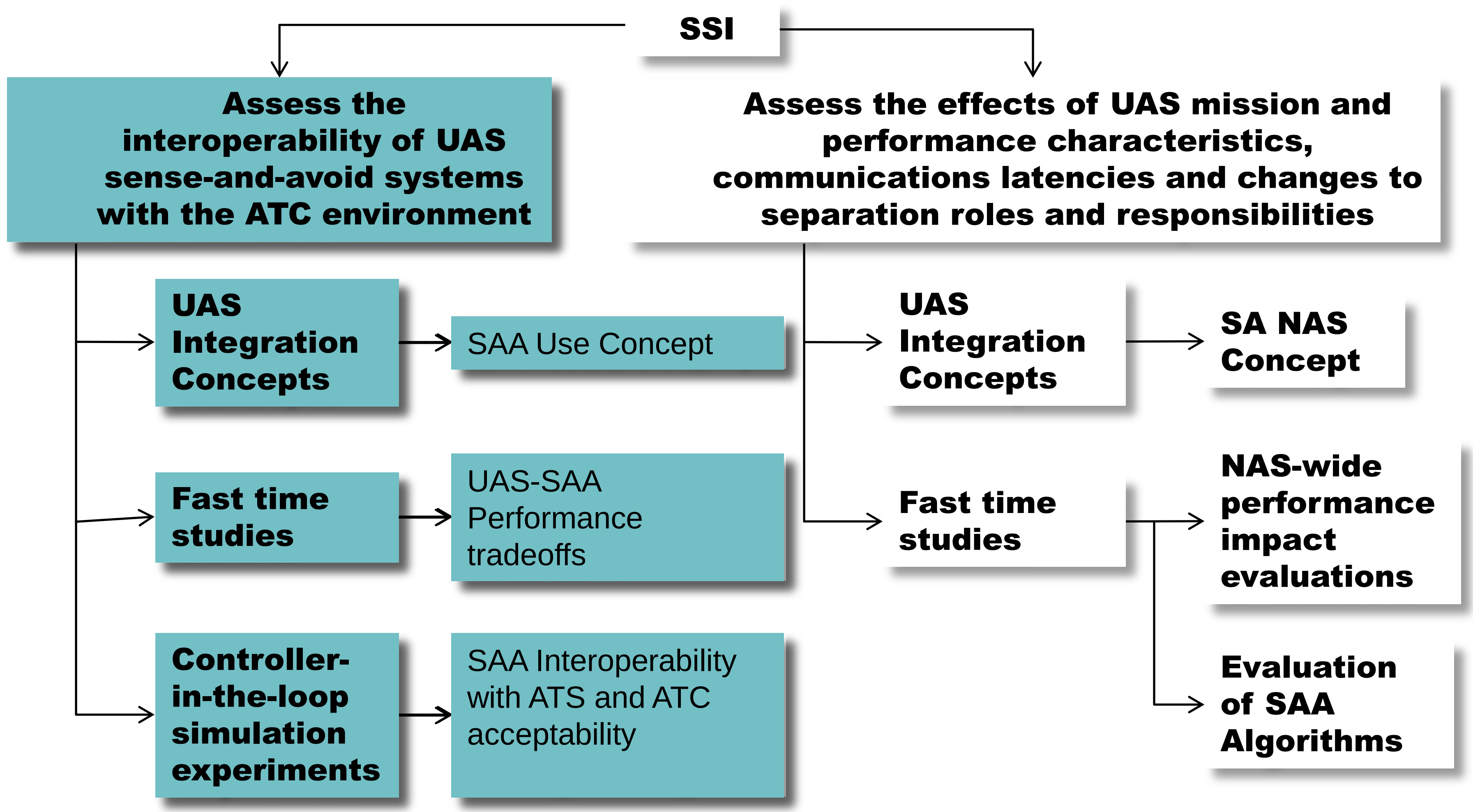
- Airspace Integration Objectives
- Technical Approach and Current Activities

SSI Subproject Objectives

Assess the interoperability of UAS sense-and-avoid systems with the NAS

Assess the effects of UAS mission and performance characteristics, communications latencies and changes to separation roles and responsibilities on the NAS

Current SSI Activities



UAS Integration Concept Background

Foundational Work

The SAA concept of integration was developed based on the design guidelines in FAA Sponsored "Sense and Avoid" (SAA) Workshop for Unmanned Aircraft Systems (UAS) October 9, 2009

Recently Published FAA Guidelines

The SAA concept of integration is inline with major operational and design considerations described in recently published documents:

- Integration of Unmanned into the National Airspace, Concept of Operations, v2.0, September 28, 2012
- Sense and Avoid (SAA) for Unmanned Aircraft Systems (UAS) Second Caucus Workshop Report January 18, 2013

Reference:

Consiglio M., Chamberlain J., Munoz C., and Hoffler K., "Concept of Integration for UAS Operations in the NAS". 28th International Congress of the Aeronautical Sciences, Brisbane, Australia, 23-28 September 2012.

Concept of Integration for UAS Operations in the NAS

A Sense and Avoid (SAA) concept for integration of UAS into the NAS was developed that rests on interoperability principles with both the Air Traffic Control (ATC) environment as well as the Traffic Alert and Collision Avoidance System (TCAS).
Specifically, the concept addresses:

- The determination of well clear values (Self Separation)
- Prevention of TCAS corrective Resolution Advisories
- Undue concern by pilots of proximate aircraft and issuance of controller traffic alerts
- Appropriate declaration times for projected losses of well clear conditions and maneuvering to regain well clear separation.

Controller-in-the Loop Assessments

Human-in-the-loop simulation experiments are under development to measure ATC impact of SAA equipped UAS

Rationale: SAA algorithms may recommend different (larger, smaller, earlier, later) maneuvers than those that might be executed by a manned aircraft pilot in the same situation. SAA technologies may have greater or lesser detection range and accuracy compared to visual target acquisition.

Research questions:

•What maneuvers are too small or too late, resulting in conflict alerts or controller perceptions of unsafe conditions?

•What maneuvers are too large (excessive “well clear” distances), resulting in behavior the controller would not expect and/or disruptions to traffic flow?

•What maneuvers are directed too early by SAA, resulting in excessive or unnecessary pilot requests to ATC for deviations?

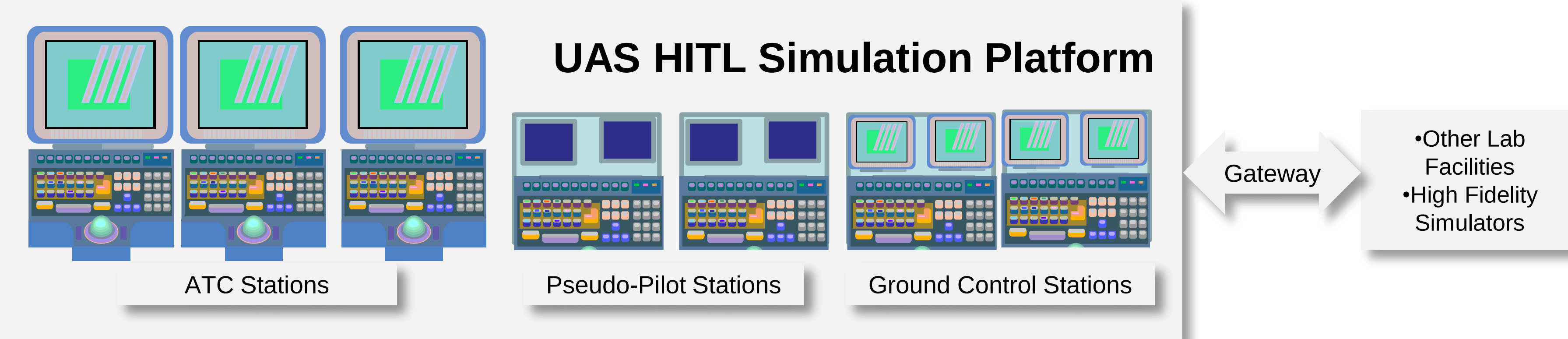
•What is the impact on the NAS of a UAS with an inability to comply with visual clearances?

Operations - Arrivals & Departures

- Procedures developed to make use of emerging technologies provide UAS with capabilities similar to those used in response to visual clearances, thereby improving access to more towered airports
- UAS are capable of following published arrival and departure routes, control instructions, and missed approach procedures
- Around major airports, UAS operations may be limited or constrained by time of day consistent with demand
- Around non-towered airports, UAS are responsible for maintaining safe distances from other aircraft in the vicinity

UAS are responsive to, and comply with all ATC instructions, and are able to integrate into local traffic patterns.

MACS-UAS: Multi Aircraft Control System Simulation

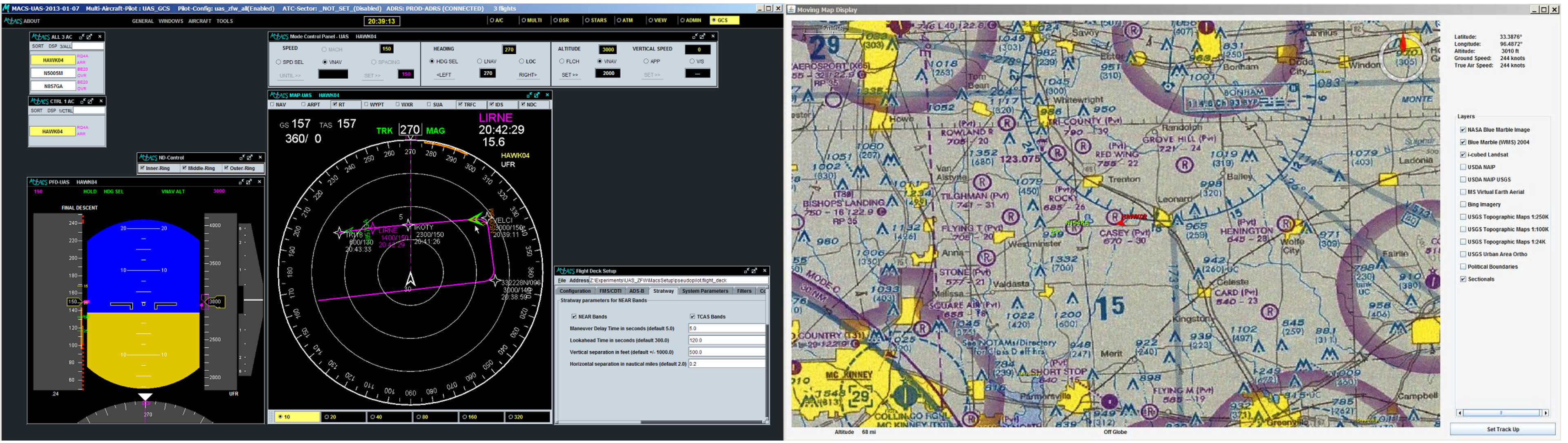


not_well_clear_detection($\mathbf{s}_o, s_{oz}, \mathbf{v}_o, v_{oz}, \mathbf{s}_i, s_{iz}, \mathbf{v}_i, v_{iz}, T$):

1. Compute sensitivity level $\ell = \mathrm{SL}[s_{oz}]$.
2. Compute relative altitude $s_z = s_{oz} - s_{iz}$ and vertical closure rate $v_z = v_{oz} - v_{iz}$.

Research SAA Pilot Interface

- Configurable delays and alerting thresholds
- Adapted NASA's Experimental SA Alerting Displays to support UAS Integration



Separation Assurance/Sense and Avoid Interoperability (SSI)

UAS-SAA Performance Trade-offs:

- Experimental estimation of the effect of UAS performance parameters and encounter geometry on the closest point of approach between two aircraft on a collision course for a range of different encounter geometries.

- Statistical design-of-experiments combined with response surface methodology are being used to strategically specify and analyze the simulated experimental runs.

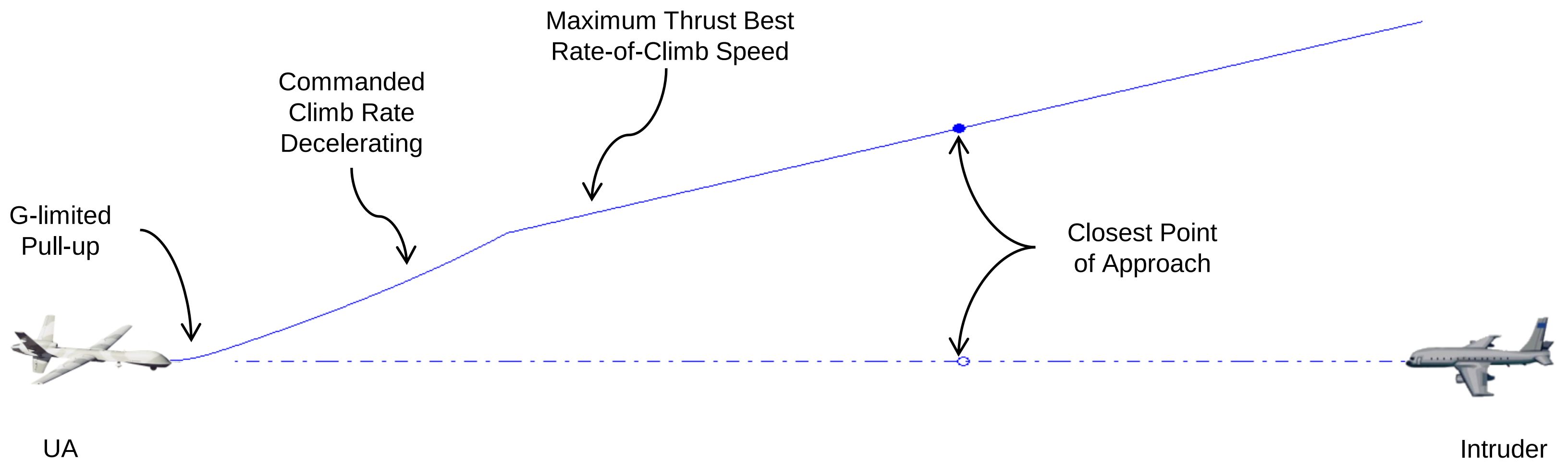
- The design of experiments approach allows for the efficient study of many factors simultaneously, fully spanning the design space, to identify and isolate the most significant factors affecting the CPA.

- The factors of interest have been grouped into those related to UAS performance and encounter geometry.

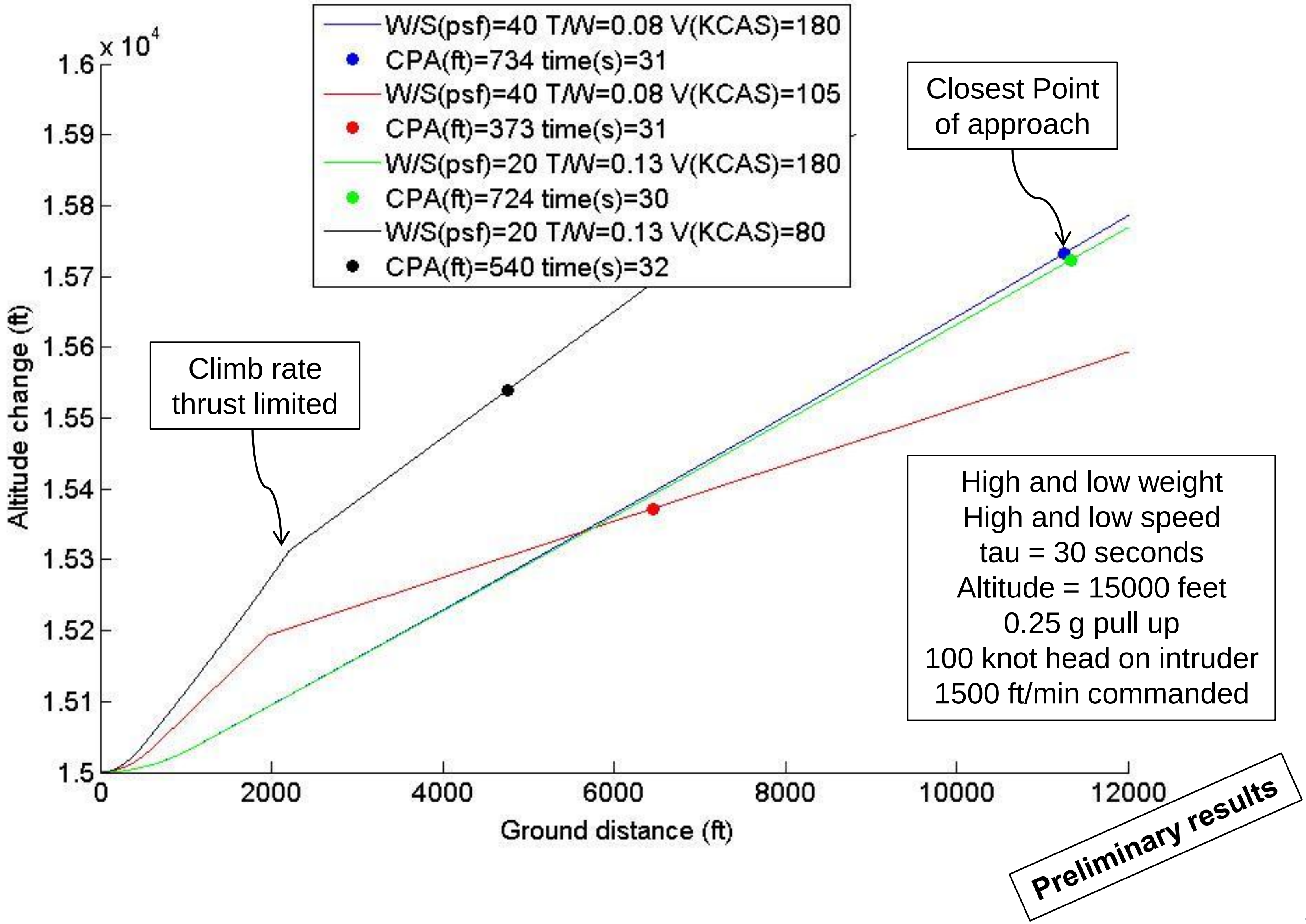
- As an example, for a vertical encounter, the following factors are currently being studied.
  - Encounter Properties: Time to Go, Encounter altitude, Intruder speed, Intruder Climb or Descent Rate, Approach Azimuth (particularly head-on vs. overtake)
  - UAS parameters: Wing Loading, Aspect Ratio, Thrust/Weight Ratio, L/D max, CL max, Initial Percent CL-max, Commanded Climb Rate, G Limit

- Evaluations will be done for UAS vertical climb, vertical descent, and level turns with appropriate performance parameters.

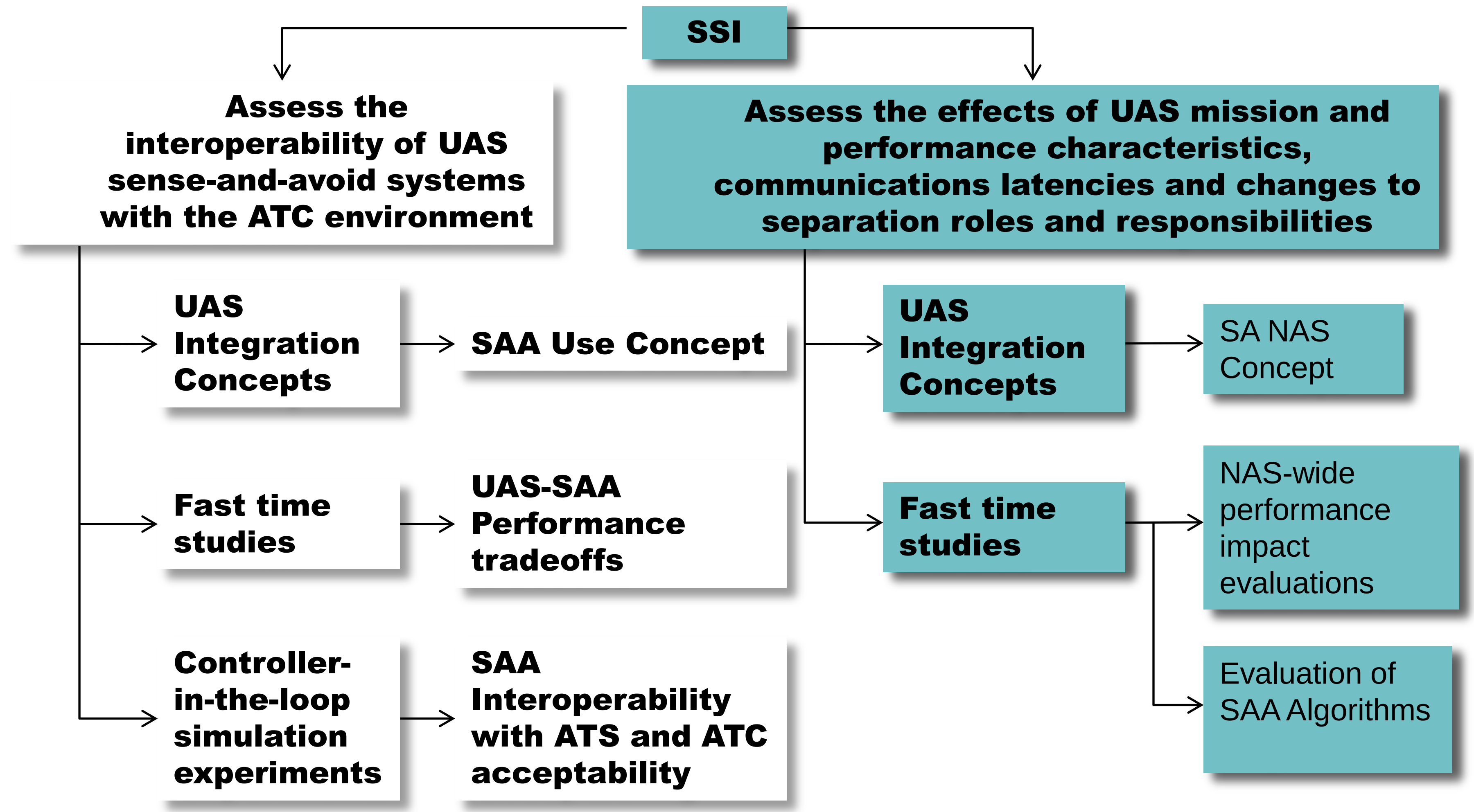
UAS Vertical Performance Limitations



Performance Comparisons With Single UAS



Current SSI Activities



Development of Concepts for UAS-NAS Integration

How do UAS-specific missions, performance, communications and SAA factors affect the capacity, safety and efficiency of the NAS?

UAS Operator at the Ground Control Station

Unmanned Aircraft

Controller

Five important components to the concept:

- Who detects and resolves conflicts?
- What information is required for conflict detection and resolution?
- What coordination is required for conflict resolution?
- Under what circumstances does responsibility change?
- Should qualitative regulations be quantified?

Questions

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Back Up Slides

Sense & Avoid (FAA ConOps)

- UAS responsibilities for safe separation
  - Self-separation
    - Analogous to ‘remain well clear’ for manned aircraft
    - Required function that applies quantitative set of values consistent with an approved airborne separation standard
    - Used by PIC when ATC services are not being provided, or when ATC authorizes the maneuver if it will exceed the tolerances of an ATC clearance

- Subset of flight crew responsibilities in conditions where pilots traditionally use their eyes to comply with 14 CFR requirements

No “Visual” Compliance

- UAS cannot comply with Visual Flight Rules (VFR) or with any clearance that includes a visual component, as these rules are based the use of human natural vision (not the use of technology to perform such functions)
- Current regulations that address the use of human visual references are not based on measurable or quantitative criteria; and therefore cannot be used as a basis for establishing instrument equivalency
- Today’s IFR provides a basis for flying without natural vision, however many visual operations exist under today’s IFR
- New regulations/rulemaking and procedures are required