Using Situation Awareness Requirements to Evaluate Systems Impact and Specify Systems Requirements

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Agenda

- **Introduction**
  - Research objective
  - Situation Awareness
  - Goal Directed Task Analysis
- **Optimized Profile Descent**
  - Capabilities
  - Operator goal analysis
  - Workload
  - Vigilance
- **Requirements Specification**
- **Conclusions and Next Steps**

NextGen Goals

- Increase NAS capacity
- Increase NAS efficiency
- Improve safety
- Reduce environmental impacts
- Increase user access to the NAS

NextGen is a massive transportation systems transformation, and a significant Human Factors challenge.

Changes in NextGen

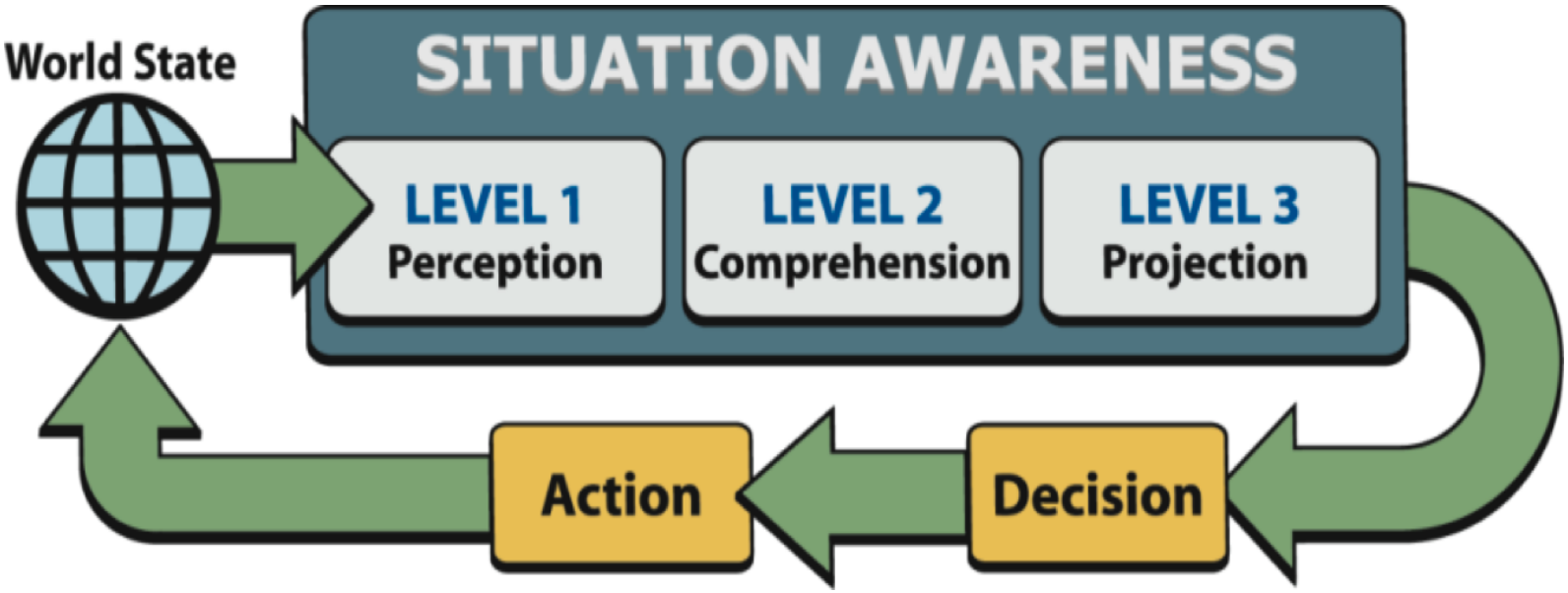
- **Revolutionary change in air transportation systems**
  - **Increased use of automation/decision aids**
  - **Extended terminal area separation standards**
  - **4-D aircraft trajectory management**
  - **Dynamic airspace configuration**
- **NextGen capabilities predicated on improvements in aircraft/ground technology**
- **Implemented through Operational Improvements (132)**
- **Challenge to develop requirements given revolutionary changes**

Research Goals

- **Assess impact of proposed NextGen Operational Improvements**
  - **Identify operator goals, decisions and SA requirements**
  - **Assess the impact of proposed capabilities on each goal**
- **Propose requirement specification guidelines**
  - **Develop sample guidelines**
  - **Identify overarching framework**
  - **Develop database for future research**

Develop a foundation for assessing impact of Operational Improvements and mitigating risk

Situation Awareness



"the perception of the elements in the environment, within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988).

SA Requirements Analysis

Cognitive Task Analysis
- Goals
  - Subgoals
    - Decisions
      - Projection Requirements
      - Comprehension Requirements
      - Perception Requirements

User Centric

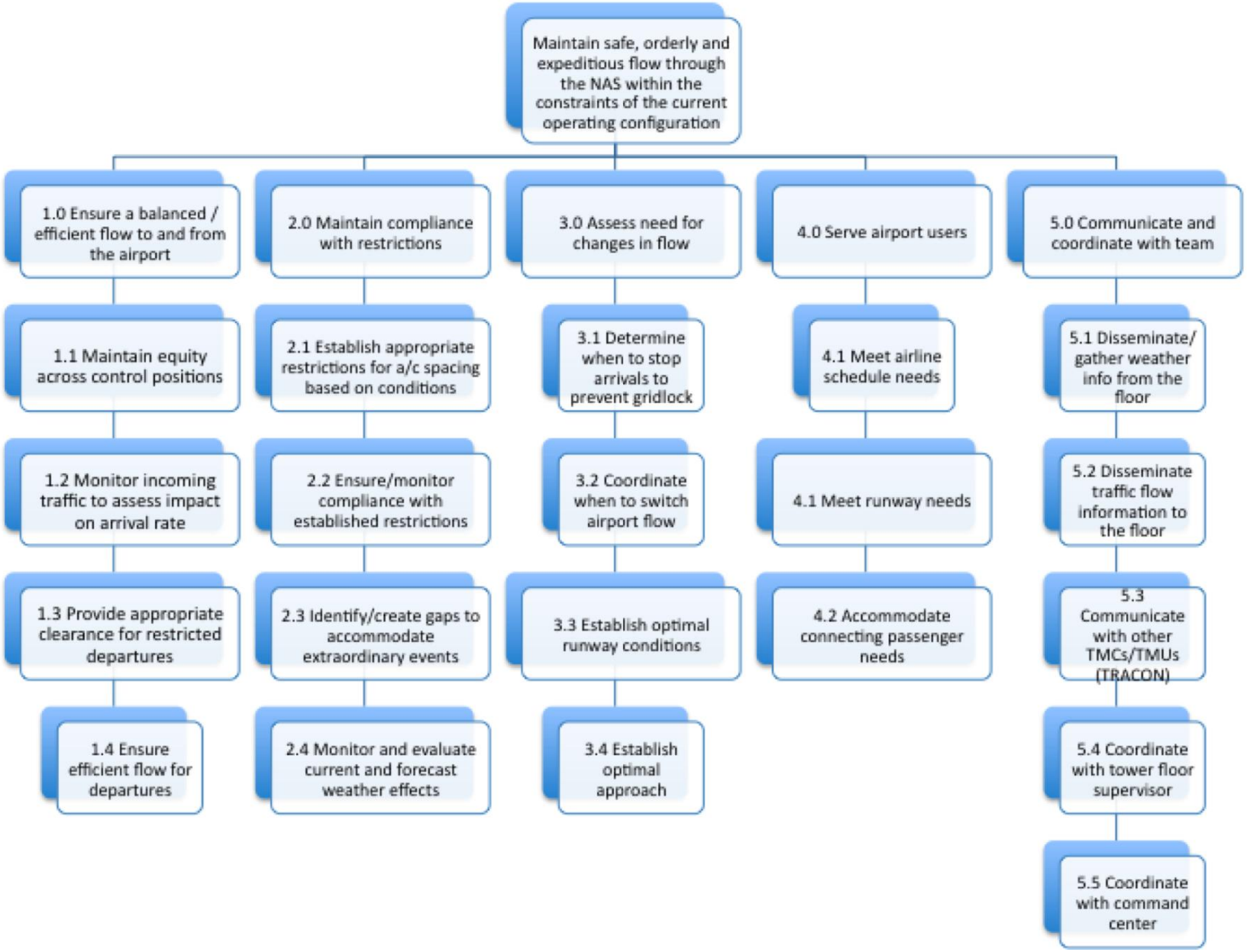
Independent of Technology

Goals remain constant

Goals/decisions portability

Traffic Management Coordinator

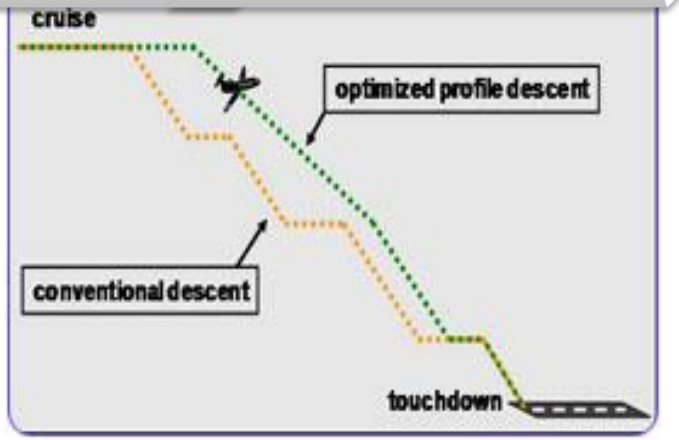
SA Technologies



Roles investigated

- **Operational improvements will affect multiple operators in the NAS**
- **Current analysis used results of completed GDTAs for:**
  - **Pilots**
  - **Terminal Radar Approach Control (TRACON) Controllers**
- **Preliminary GDTAs for:**
  - **Enroute controllers**
  - **Tower Local**
  - **Tower Ground**
  - **Flight Data Clearance Delivery**
  - **Traffic Management Coordinators**
    - Tower
    - TRACON
    - Center

Optimized Profile Descent



- **Optimized Profile Descents (OPD)**
  - **utilize continuous approach descent paths**
    - Reduce vectoring
    - Save fuel
    - Save time
  - **depend on new RNP (Required Navigation Performance)/RNAV (Area Navigation Routes)**
    - Specify a precise vertical profile,
    - Use time based metering en route and on terminal approach
- **Challenges for OPD Implementation:**
  - **Training issues for pilots/controllers**
  - **Trust issues related to new conflict resolution technologies (among others)**

Capability analysis by role

Aircraft will fly precise horizontal and vertical flight paths with minimal level offs during descent

Role	Goal affected	Impact assessment
TRACON	1.3 Ensure aircraft conformance	Increased cognitive complexity of managing a 4 dimensional route, with all 4 dimensions as dynamic aircraft variables
Pilot	2.1.7 Manage descent	Pilot may be unable to conform with a precision path of this kind manually if the Flight Management System (FMS) fails or malfunctions
Local	1.1 Ensure aircraft separation	With more precise paths that have been optimized before approach there may be less work for local controller during nominal situations.
Local	2.2 Direct arriving traffic	There may be an increased workload associated with aircraft that must do a go-around, and who must then be once again integrated into a tight flow. This may require significant work to create a gap to re-insert the aircraft into the flow.
Tower TMC	1.0 Ensure a balanced/efficient flow to and from the airport	More precise paths can lead to more aircraft per area, potentially increasing workload

Table 19: TRACON SA Requirements affected by OPD Capability

SA Requirement	Presently Available?	Preliminary Observation
Projected "time to fix" along route	No	This will be necessary to keep flow optimized as directed by TMC
Projected arrival time at airport	Indirectly	This overall goal state might need to be added to data flight blocks to aid controllers in decision making
Level of aircraft performance	No	A measure of how consistently this aircraft has hit its times at each fix
Time remaining until fix reached, based on current aircraft speed	Indirectly	May become more important to present directly if time fixes become important
Time remaining until fix reached, based on current aircraft trajectory	Indirectly	May become more important to present directly if time fixes become important
Time remaining until fix reached, based on speed option 1.	No	Could be provided by a 'What-if' analysis application,
Time remaining until fix reached, based on speed option 2.	No	Could be provided by a 'What-if' analysis application

IAD and Vigilance

Factors contributing to vigilance decrement	Impacts of IAD Capability
Target salience	The tighter spacing of aircraft translates into less time that targets will appear on screen before controllers have to respond, leading to decreased vigilance performance
Uncertainty of target location	The location of conflictions is already relatively uncertain, but the larger and more dynamic airspace for which controllers will assume responsibility leads to more uncertainty overall
Rate of background events	As terminal separation standards are pushed out into en route airspace, the density of non-event targets increases, leading to a more pronounced vigilance decrement (even if the ratio of targets to non-targets remains the same)
Sustained attention	The fatigue levels associated with sustained attention will likely increase as traffic density and the controllers' airspace responsibility increase

Requirements Specification

- **Good requirements specification can help insure that systems are designed, developed and deployed in a way that is consistent with human capabilities.**
- **Good requirements specification**
  - **Promotes system usability**
  - **Reduces development costs**
  - **Reduces operating costs**
  - **Is hard to do!!**

Characteristics of Good Requirements

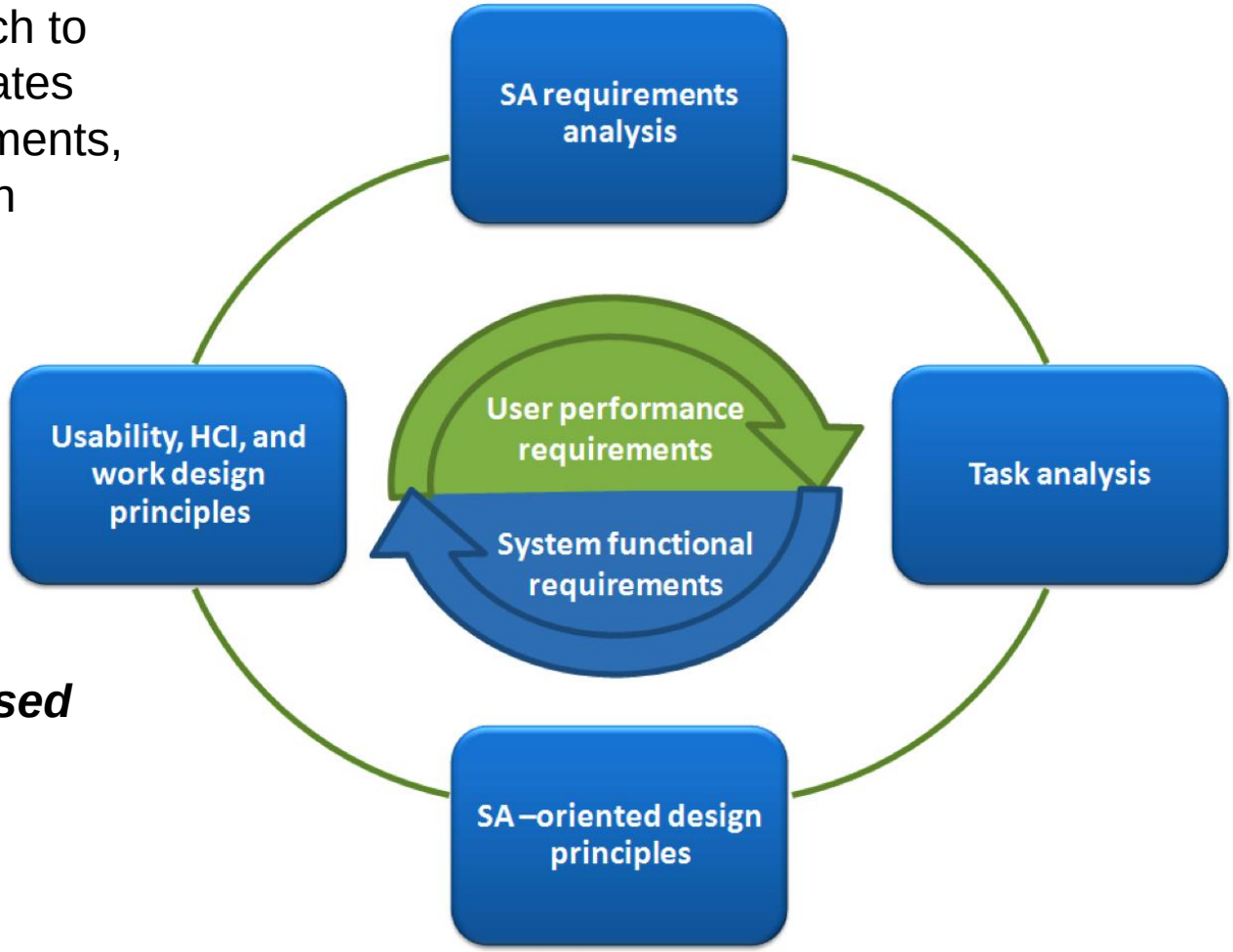
- **Achievable – consider cost, schedule, technical constraints**
- **Necessary – satisfies a documented need**
- **Verifiable and Measurable**
- **Detail Level – state "what" must happen, not "how"**
- **Complete - quantitative values are specified**
- **Consistent**
- **Format Compliance – use shall statements and appropriate formatting**

An Integrated Approach to Requirements Specification

SA Technologies

A comprehensive approach to **requirements** that integrates SA principles, SA requirements, and design guidelines with other forms of task analysis and HF design standards promotes requirements that are:

- ***Robust***
- ***Measurable***
- ***Specific***
- ***Performance-focused***



Improving Design Recommendations

Poor Design Requirements	Necessary, Clear, Achievable, Verifiable Design Requirements
Be designed to minimize user input, mechanical and perceptual errors	Operator shall be able to create air tasking order in < 120 minutes with no critical errors
Reduce manpower and personnel requirements from current levels	Total personnel required to operate system during full mission execution shall not exceed 200 (threshold), 100 (goal)
Increase accuracy, efficiency and throughput of processes with automation and integrated information	Workload for normal operations shall not be more than 60% of operator capacity
Present to and accept information from humans using a combination of visual, aural, tactile and/or other sensory methods	Operator situation awareness of critical information shall be > 95% at all times
	Operator situation awareness of non-critical mission relevant information shall be > 60%

* From Air Force Scientific Advisory Board (2004). Report on Human System Integration (AFSAB TR-04-04)

High-Level Guidelines Specifications from a GDTA

- **Hierarchical SA information needs analysis utilized to specify design recommendations**
- **Analysis identifies:**
  - **Primary information requirements**
  - **Secondary information requirements**
  - **Functional requirements of the systems**

Sample High-Level Design Requirements

- ***Primary Information Requirements (shall be persistent or viewable at-a-glance)***
  - **Aircraft altitude**
  - **Aircraft assigned altitude**
  - **Aircraft assigned airspeed**
  - **Aircraft assigned route**
  - **Aircraft groundspeed**
  - **Aircraft position**
  - **Aircraft heading**
  - **Aircraft type**
  - **Weather information to include wind direction/magnitude**
  - **Minimum safe altitude for a given sector**
  - **Minimum altitude for obstruction avoidance**
  - **Minimum IFR altitude**
  - **Terrain features to include dimensions and locations**

Sample High-Level Design Requirements for Goal 1.3

- ***Secondary Information Requirements (shall be available on-demand)***
  - **Aircraft past heading**
  - **Aircraft planned route**
  - **Projected aircraft position**
  - **Aircraft capabilities**
  - **Instrument approach procedures**
  - **Standard instrument departure procedures**
  - **Standard terminal arrival procedures**
  - **Aircraft flight plan information**
  - **Notices to Airman (NOTAMs)**
  - **Federal Aviation Regulations**
  - **Order JO 7110.X (regulations for air traffic control)**
  - **Local procedures**

Sample High-Level Design Requirements for Goal 1.3

- ***Functionality***
  - **Provide the controller with primary information requirements in dedicated regions of the display.**
  - **Provide the controller with the ability to view secondary information requirements as needed.**
  - **Alert controller if a loss of separation is impending.**
  - **Alert controller is a loss of separation occurs.**
  - **Provide the controller with aircraft track history.**
  - **Provide the controller with terrain dimension and location information.**
  - **Provide controller with all necessary airspeed (groundspeed) information**
  - **Provide controller the ability to access wind direction and magnitude information for the appropriate location/altitude.**
  - **Provide the controller the ability to project the aircraft position based on its current track.**
  - **Provide the ability for the controller to ascertain the minimum safe altitude, minimum altitude for obstruction avoidance and minimum IFR altitude for a given location.**

Using SA Design Principles for Requirements Specification

SA requirements analysis

- *Goal – Determine projected aircraft route (current)*
  - Current projection of aircraft through airspace
    - Position
    - Flight plan
    - Heading (assigned and current)
    - Altitude and altitude rate of change
    - Airspeed (assigned and indicated)
  - Weather
    - Conditions, winds
    - Impact on aircraft and airspace

Requirements statements within SA design principle:

The system shall present information related to potential aircraft conflicts on the same interface display in close proximity. The information items shall be within X in/cm or X degrees of visual arc of each other. Operators shall be able to detect aircraft conflicts in < X seconds with no critical errors.

Integrating other guidelines for extending requirements statements

Method/Approach	Guidelines and Principles	Example Requirements
Usability/HCI	System interfaces should be easy to learn and use	The system shall present aircraft parameters in consistent units across all displays and controls
Human Factors	The system design should effectively direct the user's attention by means of alerting, coding, and emphasizing techniques	The system shall alert users to aircraft conflicts using visual color cues and auditory cues. Operators shall be able to detect all alerts within X min/sec
Work Analysis and Design	The display screen should be at least 18-30 inches from the user's eyes or at arm's length	Weather information shall be presented as a focal point on a display that is proximate to the normal viewing position.

What we have done

- **Developed a systematic methodology for assessing the impact of proposed changes on operator SA through goal analysis**
- **Developed validated GDTAs for Pilots and TRACON controllers**
- **Developed preliminary GDTAs for Enroute, Tower Ground, Local and Flight Data Clearance Delivery Controllers, Tower, TRACON and Enroute TMCs**
  - **Even preliminary GDTAs provide valuable guidance**
- **Demonstrated method for translating SA Requirements analysis into requirements specification**

What we will do next

- Currently validating two additional GDTAs
- Will continue to validate other GDTAs
- Starting new project to establish research basis for assigning values to placeholder requirements
  - Establish range of values, based on best research available, for constructs such as reliability, accuracy, false alarms
- Add additional column to impact table to identify requirements that mitigate any negative impact

Questions?

Potential impacts of OPD on TRACON

NextGen 2018 Difference	Goal Affected	Potential Cognitive Impact
Aircraft will fly precise horizontal and vertical flight paths with minimal level offs during descent	1.3 Ensure aircraft conformance	Increased cognitive complexity of managing a 4 dimensional route, with all 4 dimensions as dynamic aircraft variables
Aircraft will be equipped (RNP: Required Navigation Performance) to arrive over fixes at specific times	1.3 Ensure aircraft conformance	The need to represent schedule divergence/conformance information (eg“time to fix”) to the controller is introduced
	2.2 Manage arrivals	Higher workload due to timing considerations in addition to spacing considerations
Aircraft will be able to hold more precise paths while staying properly spaced to facilitate higher runway utilization	2.2 Manage Arrivals	Higher workload as more planes per time period enter sector
	1.3 Ensure aircraft conformance	Reduced workload if the aircraft can now be required to maintain its own precise path

Pilot SA Requirements affected by OPD Capability

SA Requirement Affected	Presently Available?	Preliminary Observation
Projected path of other aircraft	Indirectly	Pilot will have to rely more heavily on the computer to control the aircraft. Therefore making projections for separation purposes may be less demanding.
Location of wake turbulence	Indirectly	
Projected position *x* at time *t*	Indirectly	
Projected Aircraft – Routes – Current	Indirectly	Pilots will be more reliant on automation to resolve conflict issues in order to maintain sequencing and assigned arrival times.
Aircraft relative locations	Indirectly	
Time required to perform maneuver	No	
Deviation between planned descent profile and optimal profile	No	Pilot will have to rely on the onboard computer for projections, but this may actually decrease cognitive load.
Estimated time of arrival at destination	Yes	
Projected deviation from arrival schedule	No	Since descent is virtually continuous, pilot will have to complete cockpit flows and checklists in a timely manner—there may be little time to "catch up" without step-downs.
Planned cruise altitude	Yes	Pilots will have less input into how the aircraft optimizes the descent profile, therefore, greater vigilance may be required to ensure the aircraft performs as expected.
Planned vertical speed	Yes	
Projected fuel usage in planned descent profile	Yes	
Aircraft- Level of control	Yes	

Coupling SA requirements with SA design principles

SA Technologies

- **High-level requirements provide valuable guidance for requirements specification**
- **Designers can then combine the results of this analysis with SA-oriented design principles**
- **These principles are grounded in empirical research and SA theory**
  - **Focus on presenting the right information to operators at the right time**
  - **Reduced cognitive loading**
  - **Accurate representations of uncertainty to foster trust**