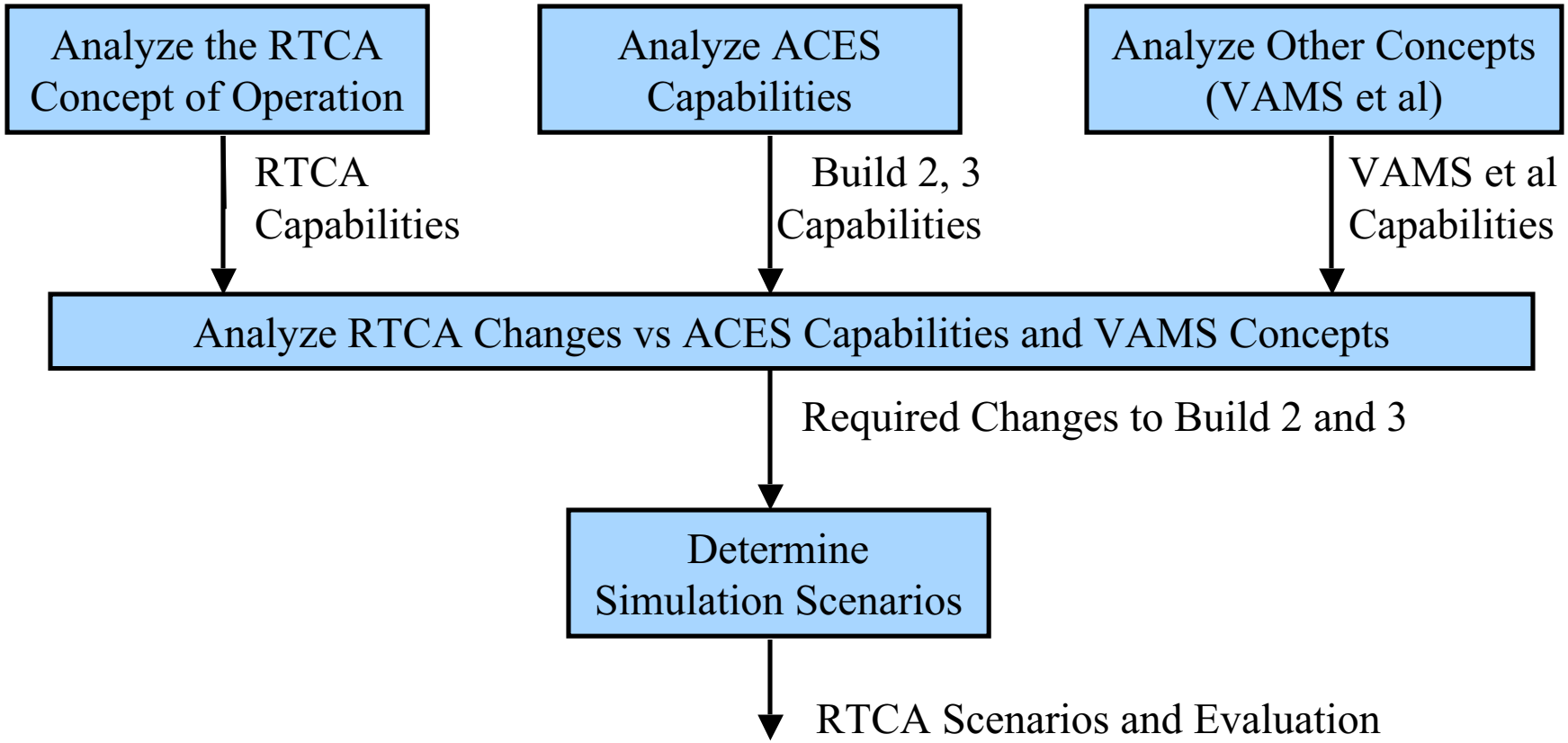
Required ACES Capabilities to Simulate the RTCA Concept of Operation

February 2004

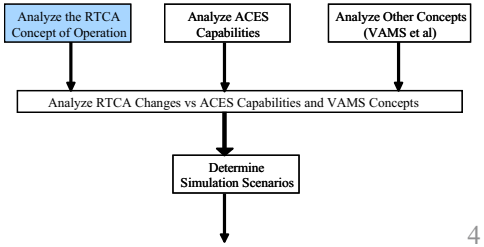
Purpose

- Identify what is required of ACES to simulate the RTCA Concept of Operation (CONOPS)
  - Identify the key elements of the RTCA CONOPS
  - Identify how much of the RTCA CONOPS that Builds 2 and 3 can simulate
  - Determine the changes to Build 2 that are required to fully simulate the RTCA CONOPS
  - Identify other concepts that, if simulated in ACES, might provide some of the modifications required to simulate the RTCA CONOPS
- Develop candidate simulation scenarios to evaluate the RTCA CONOPS

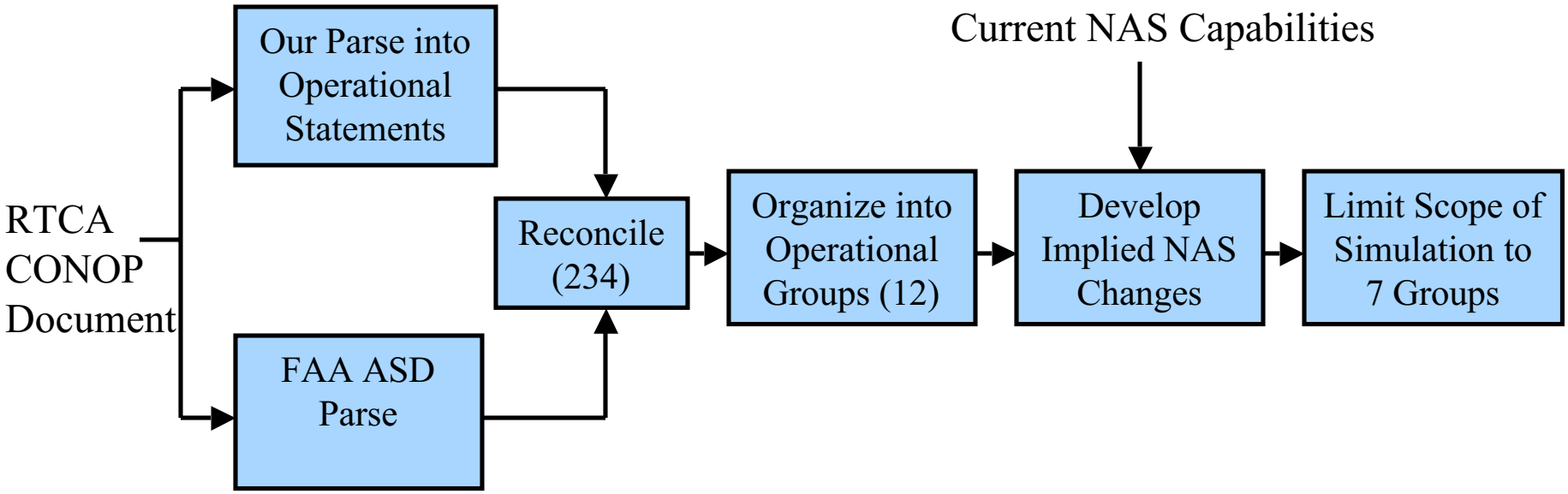
Overall Approach



Analyze the RTCA Concept of Operation



Approach


RTCA CONOP Document
Our Parse into Operational Statements
FAA ASD Parse
Reconcile (234)
Organize into Operational Groups (12)
Current NAS Capabilities
Develop Implied NAS Changes
Limit Scope of Simulation to 7 Groups

RTCA Analysis Approach

- Decompose the RTCA CONOPS into a set of "Operational Statements" and reconcile with FAA ASD set – 234 resulted
- Reword and group the 234 Statements into like items (called Operational Groups here) that might relate to a simulation requirement– 12 Operational Groups resulted
  - **Situational Awareness**
  - **Strategic Flow Management**
  - **Tactical Flow Management**
  - **Separation Assurance**
  - **Airspace Design and Management**
  - **Emergency and Alerting**
  - **Infrastructure/Information Management**
  - **CNSi* Infrastructure**
  - **Airports Infrastructure**
  - **Failure Modes**
  - **Standards**
  - **Services to Support Space and UAV Operations**

FAA Services

*CNS + Information Infrastructure

RTCA Analysis Approach (continued)

- Operational Statements and Operational Groups were eliminated that:
  - Were clearly beyond the scope of the simulation (e.g., emergency and alerting, failure modes)
  - Do not explicitly impact NAS performance (e.g., adherence to standards, infrastructure management)
- 7 Operational Groups and 218 Operational Statements were left
  - Situational Awareness
  - Strategic Flow Management
  - Tactical Flow Management
  - Separation Assurance
  - Airspace Design and Management
  - CNSi Infrastructure
  - Airports Infrastructure
- Next the Operational Statements were allocated to Operational Groups

Capabilities Required by RTCA CONOPS

- Situational Awareness
  - Cockpit Tools
  - ATSP Tools
  - AOC Tools
- Strategic Flow Management
  - National Flow Planner
  - En Route Flow Planner
  - Terminal Flow Planner
  - Surface Flow Planner
  - Collaborative Decision Making Tools
- Tactical Flow Management
  - National Flow DST
  - En Route DST
  - Terminal DST
  - Surface DST
  - Collaborative Decision Making Tools

Capabilities Required by RTCA CONOPS (continued)

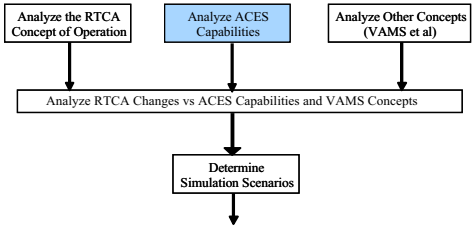
- Separation Assurance Tools
  - Self Merging and Spacing
  - Self Separation
  - Improved CD&R
- Airspace Design and Management in RTCA
  - Expanded and More Flexible Routes
  - Larger Sectors and Facility Boundaries
  - Dynamic Airspace Management
- CNSi Infrastructure in RTCA
  - Precision approaches to all runway ends
  - Data link
  - TIS and ADS-B
  - Improved surveillance coverage in domestic and oceanic airspace
- Airports Infrastructure in RTCA
  - New runways; use all suitable runways at 5400 public use airports
  - Shortened runway occupancy time
  - Larger aircraft use smaller airports

RTCA Analysis Approach (continued)

- The 218 Operational Statements were categorized as to what they would require to evaluate within the simulation
  - The "effect" of some could be evaluated by adjusting the inputs to ACES (e.g., flight plan data, geographic airspace boundaries, sector capacities, airport arrival and departure rate limits (AAR/ADR)[1]
  - Many would require additions of ATC/AOC/TFM/FD functionality in the form of Planners (strategic) and DSTs (tactical) algorithms
  - A few required inclusion of models of the pilot, AOC, and controller behaviors
  - Most would require models of weather and impacts of weather as effects or impacts on planners or DSTs

[1]Raytheon used this approach for assessing impacts of increased sector capacities and airport arrival rate limits

Analyze Current and Planned ACES Capabilities



Assumed Build 2 Capabilities[1]

- Situational Awareness – Not explicitly modeled
- Strategic Flow Management
  - En route congestion assessment and resolution
  - AOC flight delay and cancellation model
- Tactical Flow Management
  - Surface Traffic Limitations
  - User Adjustable Runway Arrival and Departure Capacities
  - Advanced Airspace Concept (AAC) to increase en route sector capacities
- Separation Assurance
  - Horizontal and vertical CD&R
  - Automated CD&R (via AAC)
- Airspace Design and Management - Existing and future routes and static airspace structures can be used
- CNSi Infrastructure – Not explicitly modeled
- Airport Infrastructure – Any airport with arriving or departing flights can be simulated at low fidelity

[1]Extracted from Build 2 Description from ACES Phase 3 Summary Document

Assumed Build 3 Capabilities[2]

- Strategic Flow Management
  - Separation of Strategic (ATCSCC) Truth Data
  - Runtime modification of sector capacities
  - Generate and fly new flight plans
  - Capability to support rerouting
- Tactical Flow Management
  - Time based metering
- Airspace Design and Management
  - Multiple Terminal Boundary Fixes
  - Runway and Fix Assignments
  - Individual Runway Identification
  - Multiple Airports per TRACON
  - Meter Fix – Runway Airspace Node Network
  - Terminal Airspace Flexible Node Network
  - Representative Set of Terminal Areas

[2] Extracted from Draft CTO 7.34 – Phase 4 Program Management Plan, amended

Assumed Build 3 Capabilities (continued)

- Other new capabilities
  - International flights
  - Flights filtered by null sector boundaries

Other Future Build Capabilities to Fully Evaluate RTCA CONOPS via ACES

- High fidelity surface model and associated surface DST
- Tools for Flight Deck, ATSP, AOC Situational Awareness
- Planners and DSTs for the
  - Separation Assurance
  - Strategic Traffic Flow Management
  - Tactical Traffic Flow Management
  - AOCs Operations
- Oceanic flight simulations
- Space vehicle flight simulations
- Space vehicle Planners and DSTs
- Realistic pilot and controller models
- Additional error models for CNSi Infrastructure
- Security response models (e.g., dynamic no fly zones)

Analysis of RTCA Requirements vs ACES Capabilities (continued)

- Coverage of 218 Operational Statements were judged to be
  - Green (can be directly simulated in ACES)
  - Blue (effect can be simulated in ACES)
  - Green (can be directly or indirectly simulated with ACES)
  - Red (cannot be assessed using ACES)
- Percent coverage

	Build 2	Build 3	Future Builds
Yellow	22%	33%	100 %
Blue	33%	34%	0%
Blue+Yellow	55%	67%	100%
Red	45%	33%	0%

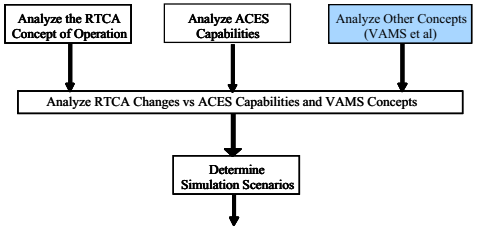
Build 2/3 can evaluate

Situational Awareness
Cockpit Tools
ATSP Tools
AOC Tools
Tactical Flow Management
Terminal Planner
Terminal DSTs
Surface DSTs
Separation Assurance Tools
Self Merging and Spacing
Self Separation
Improved CD&R

Build 3 can simulate

Airspace
Expanded and More Flexible Routes
Larger Sectors and Facility Boundaries
CNSi
Precision approaches to all runway ends
Data link
Improved surveillance coverage in domestic and oceanic airspace
Airports
New runways; use 5,400(+) airports
Shortened runway occupancy time
Larger aircraft use smaller airports

Analyze Other Concept Capabilities (VAMS et al)



Analysis of Other Concepts

- Based upon study of descriptions of VAMS, AATT, SATS, and FAA TSD concepts
- Aided by analysis of VAMS Functionality vs VAMS Concepts[3]

[3]Extracted from VAMS Concept Require#73FE3.pdf

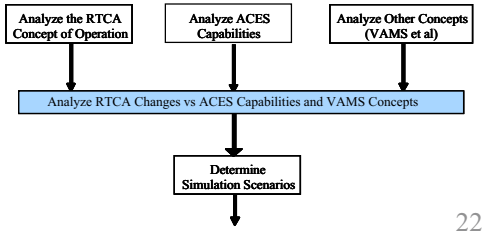
Concepts Examined

- Gate-to-Gate Concepts
  - Boeing 2020 Capacity Increasing Concept
  - Seagull Massive Point to Point (PTP)
  - NASA System Wide Optimization (SWO)
  - NASA Advanced Airspace Concept (AAC)
  - NASA Distributed Air/Ground Concept Elements 5, 6, 11 (DAG)
  - NASA SATS
  - FAA Target System Description (TSD)
  - NG Centralized Terminal Operation Control (CTOC)
  - Metron Weather (M Wx)
  - NASA University Concepts (UC)

Concepts Examined (continued)

- En Route Concepts
  - NASA System Wide Evaluation and Planning Tool (SWEPT)
  - NASA En Route Descent Advisor (EDA)
  - NASA Direct To (D2)
  - NASA TMA Multi Center (TMA MC)
  - NASA Regional Metering (RM)
- Terminal Concepts
  - Raytheon Terminal Area Capacity Enhancing Concept (TACET)
  - Metron Surface (M S)
  - Optimal Synthesis Surface (OS S)
  - NASA Wake Vortex Avoidance System (Wake VAS)
  - NASA Surface Management System (SMS)

Analysis of RTCA vs ACES vs VAMS Concepts



Coverage of RTCA Requirements by Various Concepts

	Gate to Gate										Terminal					En Route				
RTCA Requirements	Boeing	PTP	SWO	AAC	DAG 5/6/11	SATS	FAA TSD	NG CTOC	M Wx	UC	TACET	M Surf	OS Surf	Wake VAS	SMS	SWEPT	EDA	D2	TMA MC	RM
Situational Awareness																				
Cockpit Tools	Red	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red	Red
ATSP Tools	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
AOC Tools	Yellow	Red	Red	Red	Red	Red	Red	Red	Yellow	Red	Red	Red	Red	Red	Yellow	Yellow	Red	Red	Red	Yellow
Strategic Flow Management																				
National Planner	Green	Red	Green	Red	Red	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red	Red	Green	Red	Red	Red	Yellow
Collaborative Decision Making Tools	Green	Red	Green	Red	Red	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red	Red	Green	Red	Red	Red	Yellow
Tactical Flow Management																				
En Route Planner	Green	Red	Green	Green	Yellow	Red	Yellow	Red	Yellow	Yellow	Red	Red	Red	Red	Red	Yellow	Yellow	Yellow	Green	Yellow
En Route DSTs	Yellow	Red	Yellow	Green	Yellow	Red	Yellow	Red	Yellow	Yellow	Red	Red	Red	Red	Red	Red	Yellow	Yellow	Yellow	Green
Terminal Planner	Green	Yellow	Green	Green	Yellow	Red	Yellow	Red	Yellow	Yellow	Green	Red	Red	Yellow	Red	Red	Red	Red	Yellow	Yellow
Terminal DSTs	Yellow	Yellow	Yellow	Green	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Green	Red	Red	Red	Red	Red	Red
Surface DSTs	Red	Red	Yellow	Red	Red	Red	Yellow	Red	Yellow	Red	Red	Green	Green	Yellow	Yellow	Red	Red	Red	Red	Red
Collaborative Decision Making Tools	Yellow	Red	Yellow	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Yellow	Red	Yellow	Red	Red	Yellow	Red	Red
Separation Assurance Tools																				
Self Merging and Spacing	Yellow	Yellow	Red	Red	Green	Green	Green	Red	Red	Green	Yellow	Red	Red	Red	Red	Red	Red	Red	Red	Red
Self Separation	Yellow	Green	Red	Red	Green	Green	Green	Red	Red	Green	Yellow	Red	Red	Red	Red	Red	Red	Red	Red	Red
Improve CD&R	Yellow	Green	Red	Green	Green	Green	Green	Red	Red	Green	Yellow	Green	Green	Red	Red	Red	Red	Red	Red	Red
Airspace Design and Management																				
Expanded and More Flexible Routes	Red	Yellow	Yellow	Yellow	Green	Yellow	Red	Red	Red	Yellow	Yellow	Red	Red	Yellow	Red	Red	Red	Red	Red	Red
Larger Sectors and Facility Boundaries	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red	Yellow	Red	Red	Red	Red	Red	Red	Red	Red	Yellow	Red
Dynamic Airspace Management	Red	Red	Yellow	Yellow	Red	Red	Red	Red	Red	Yellow	Red	Red	Red	Red	Red	Red	Red	Red	Yellow	Red
CNSi Infrastructure																				
Precision approaches to all runway ends	Green	Green	Green	Green	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Red	Red	Red	Red	Red
Data link	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Red	Red	Red	Red	Red
Improved surveillance coverage in domestic	Green	Yellow	Yellow	Yellow	Yellow	Green	Green	Yellow	Red	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red	Red
Airports Infrastructure																				
New runways; use 5400 airports	Green	Green	Green	Green	Red	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Red	Red	Red	Red	Red
Shortened runway occupancy time	Red	Yellow	Red	Red	Red	Green	Red	Red	Red	Red	Yellow	Red	Red	Yellow	Yellow	Red	Red	Red	Red	Red
Larger aircraft use smaller airports	Red	Green	Red	Red	Red	Green	Red	Red	Red	Red	Yellow	Red	Red	Yellow	Yellow	Red	Red	Red	Red	Red

Concept Source	
	VAMS
	AATT
	Other

Coverage Key	
	Included in concept
	Somewhat included
	Not included

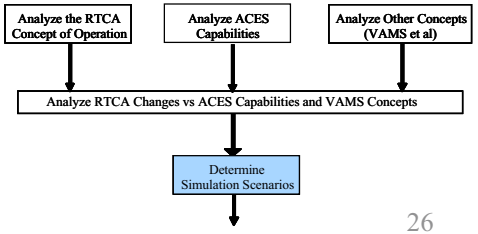
Conclusions of Analysis of Other Concepts

- Products of other concept developments (e.g., VAMS, AATT) can be instrumental in providing:
  - Values of ACES input variables to create the effect of such concepts
  - The algorithms/tools that mechanize the concepts
- Products of other concepts can form the basis for most of the required additions of future builds

With New Agents and Models, Future Builds Can Simulate (potential source shown in parentheses)

Situational Awareness	
Cockpit Tools	Pilot Model (real time sims)
ATSP Tools	Controller Model (real time sims)
AOC Tools	AOC Model (real time sims)
Strategic Flow Management	
National Planner	Agent (Boeing; SWO, SWEPT)
Collaborative Decision Making Tools	Agent (Boeing, SWO, SWEPT)
Tactical Flow Management	
En Route Planner	Agent (Boeing, SWO, AAC, TMA MC)
En Route DSTs	Agent (AAC, RM, D2)
Terminal Planner	Agent (Boeing, SWO, AAC, TACET, WVAS)
Terminal DSTs	Agent (AAC, TACET, WVAS)
Surface DSTs	Agent (M Surf, OSI Surf, SMS)
Collaborative Decision Making Tools	Agent (Boeing, SWO)
Separation Assurance Tools	
Self Merging and Spacing	Agent (DAG, SATS, TSD, UC)
Self Separation	Agent (PTP, DAG, SATS, TSD, UC)
Improved CD&R	Agent (Boeing, PTP, SWO, AAC, TACET, DAG)
Airspace	
Dynamic Airspace Management	Agent

RTCA Simulation Scenarios and Evaluations



Scenario Assumptions

- Perfect Communications, Navigation, Surveillance, Weather Data
- No System Failures or Blunders
- Precision approaches available at all airports
- Security will not be simulated
- Situational Awareness effects do not need to be simulated directly
- All information is available to all agents at all time (no connectivity, bandwidth or latency issues)
- Aircraft will have variable equipage
- 6 weather days will be required to characterize the NAS *

* "A Cluster Analysis to Classify Days in the NAS" Roth, Krozel et al; AIAA Navigation and Control Conference; August 2003

Scenario Definition and Characteristics

- Forecasts
  - Time Period (e.g., 2003, 2015, 2022)
- Demand
  - Flight Plans (e., O/D, fleet mix, and schedules)
- System
  - Aircraft Characteristics (e.g., Models)
  - Airports Characteristics (e.g., Locations, AAR/ADR)
  - Airspace Characteristics (e.g., Sectorization, Capacities)
  - CNSi (not simulated; assumed perfect)
  - Separation Standards (e.g., current, reduced)
  - TFM (e.g., Planning, Collaboration, DSTs)
  - Human Factors (included in Scenario Evaluation Metrics)
- Environment
  - Weather (e.g., aloft, ground)
  - Security (not simulated)

RTCA Scenario Characteristics

Forecasts	Flight Plans	Aircraft	Airports & Airport Capacity	Airspace/Routes
Current Days 5/17; 5/26	IFR	Commercial	5400 + new	Static SUA
Other Current Days (TBD)	VFR	GA	New Runways	Dynamic SUA
OEP/TSD (2015)	No Flight Plans	VTOL	Dynamic AAR/ADR	Dynamic Resectorization
LMI	3D	UAV	Dynamic Taxi Time	ALTRV for Space Vehicles
2X Current	4D	Military		Transitional Routes
3X Current	International			Offset Approaches
				Parallel Routes
				Flexible Oceanic Routes
Separation Standards	**Weather**	**ACES Operating Modes**	**ACES Models Normal/Local**	Large Sectors & Facility Boundaries
Reduced Separation Stds	Good	Normal	Oceanic; Low Fi/Hi Fi	Dynamic Sector Capacities
Sep Stds based on equipage	Bad	Local	En Route; Hi Fi/Hi Fi	Flexible Entry Points
Dynamic Sep Stds	Ugly		Terminal; Low Fi/Hi Fi	
	Poor forecasts		Surface; Low Fi/Hi Fi	

Beyond the current NAS

RTCA Scenario Characteristics (cont)

National TFM	En Route TFM	Terminal TFM	Airport TFM	AOC/Aircraft
Planner	**Planner**	**Planner**		**Planner**
Strategic	Strategic	Strategic	VMC rates in IMC	Strategic
	Tactical	Tactical		Tactical
Collaboration	**Collaboration**	**Collaboration**		**Collaboration**
Auto-Negotiation	Auto-Negotiation	Auto-Negotiation		
DSTs	**DSTs**	**DSTs**	**DSTs**	**DSTs**
Conflict Probe & Res	Conflict Probe & Res	Conflict Probe & Res	Surface Conflict	Conflict Probe & Res
Develop TFM Initiatives	Time Based Metering	Time Based Metering	Rwy Incursion	
Collaborative Rerouting	Collaborative Rerouting	Collaborative Rerouting	Smart Sensors	
Dynamic Routes	Dynamic Routes	Dynamic Routes	Dynamic Routes	
3D, 4D, RTA, CTA	3D, 4D, RTA, CTA	3D, 4D, RTA, CTA	2D, 3D	3D, 4D, RTA, CTA
Airspace Configuration	SUA Reroutes	Speed Control		Conflict Detection & Res
Wx effects(include poor forecasts)	Wx effects(include poor forecasts)	Wx effects(include poor forecasts)	Wx effects(include poor forecasts)	Wx effects(include poor forecasts)

Note: A specific scenario can include a single RTCA characteristic in order to evaluate the impact on the NAS or all of the characteristics taken together for an overall evaluation

Proposed RTCA Evaluation Metrics

Capacity

- Total flights flown per simulation day (Traffic volume)
- Daily arrival capacity
- Daily departure capacity
- Total System Delay by category (arrivals, departures, enroute)
- Total System Delay by Cause (e.g., weather, terminal volume)
- Time required for surface movement
- System Delay by Airport
- Number of Gate Delays
- Gate Delay minutes

Throughput

- Number of operations by En route Sector
- Total number of operations across all en route sectors
- Number of Landings and Takeoffs by Airport
- Total number of Landings and Takeoffs across all Airports

Safety

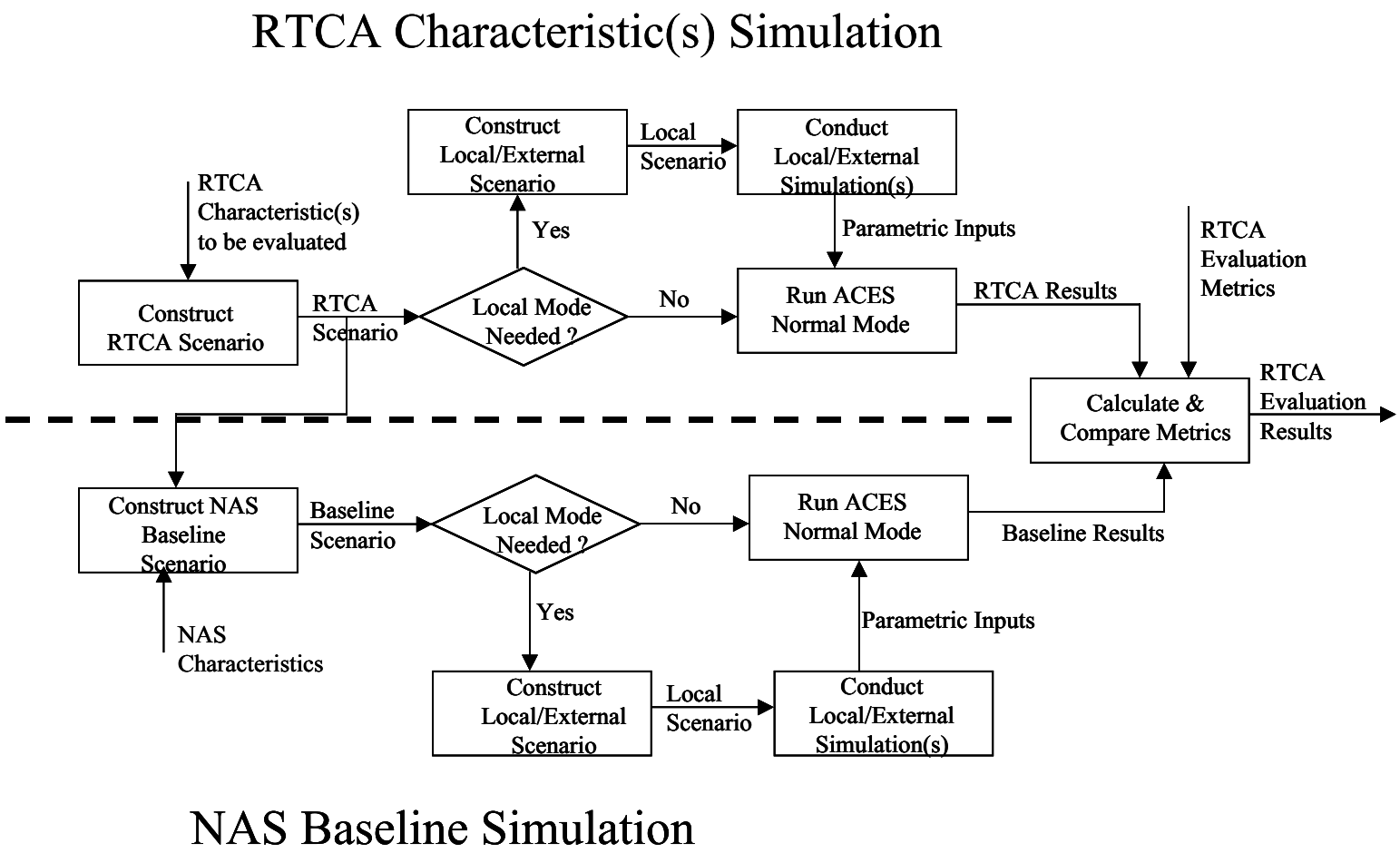
- Number of Separation Violations

Proposed RTCA Evaluation Metrics (continued)

Efficiency

- Total aircraft travel time
- Total fuel consumed
- Average taxi time from pushback to wheels up
- Average taxi time from wheels down to docking
- Ratio of system delay to number of flights (average delay/flight)
- On-time performance
- Cancellations

Human Factors (e.g., workload, training for tasks and procedures)

- Number of Monitor Alerts
- Number of Ground Stops and Ground Holds
- GDP and GS minutes
- Number of CD&R Interventions
- Number of TFM Maneuvers

Proposed RTCA Evaluation Process