Coordination of Fast-Time and Real-Time Simulation Activities

[*Implications for Scenario Design*]

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Introduction

- Topic 1 – Coordination of fast-time and real-time human-in-the-loop simulations
  - Applications: When to Use Fast-time (FT) modeling and simulation (M&S) and Real-Time (RT) simulations
  - Optimizing
  - Data sharing between FT M&S and RT simulations
  - Reuse and standardization

Presentation Outline

- Validation purpose, our role, and validation process
- FT M&S and RT potential disconnect
- Connection between FT M&S and RT
- FT M&S and RT coordination examples
- FT M&S and RT coordination process
- Ideas for guidelines
- Some challenges
- Suggestions for FT M&S and for RT
- Optimization
- Conclusions

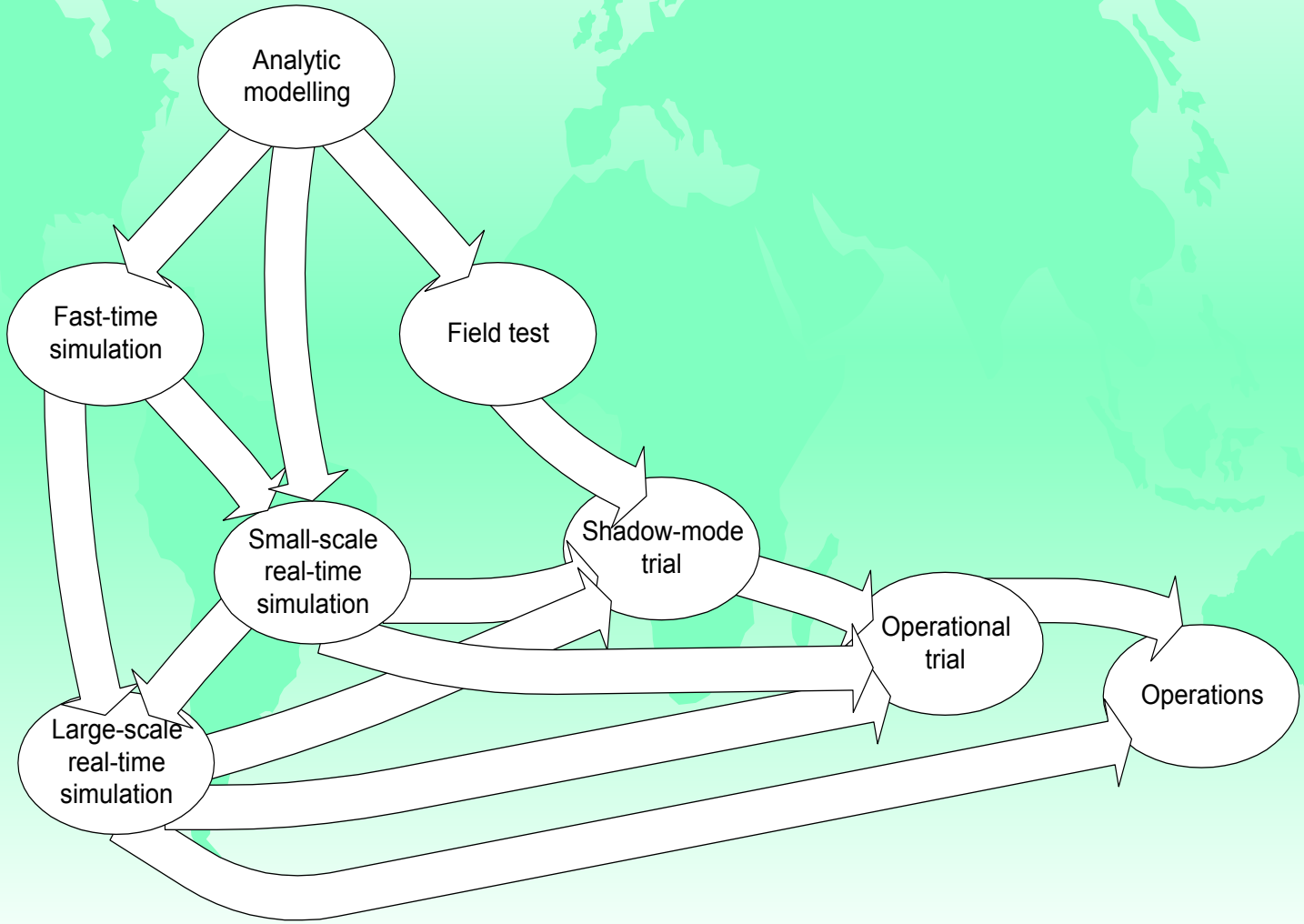
Validation Focus

- Modernization program validation activities have to demonstrate feasibility, benefits, and cost-benefit trade-off
- Feasibility
  - Supports operational objectives, human performance, usability, stakeholder acceptance, etc.
- Benefits
  - Capacity, predictability, accessibility, scalability, flexibility, efficiency, and safety on a large-scale
- Cost-Benefits
  - Cost of operations and their relation to benefits
- Risk analysis

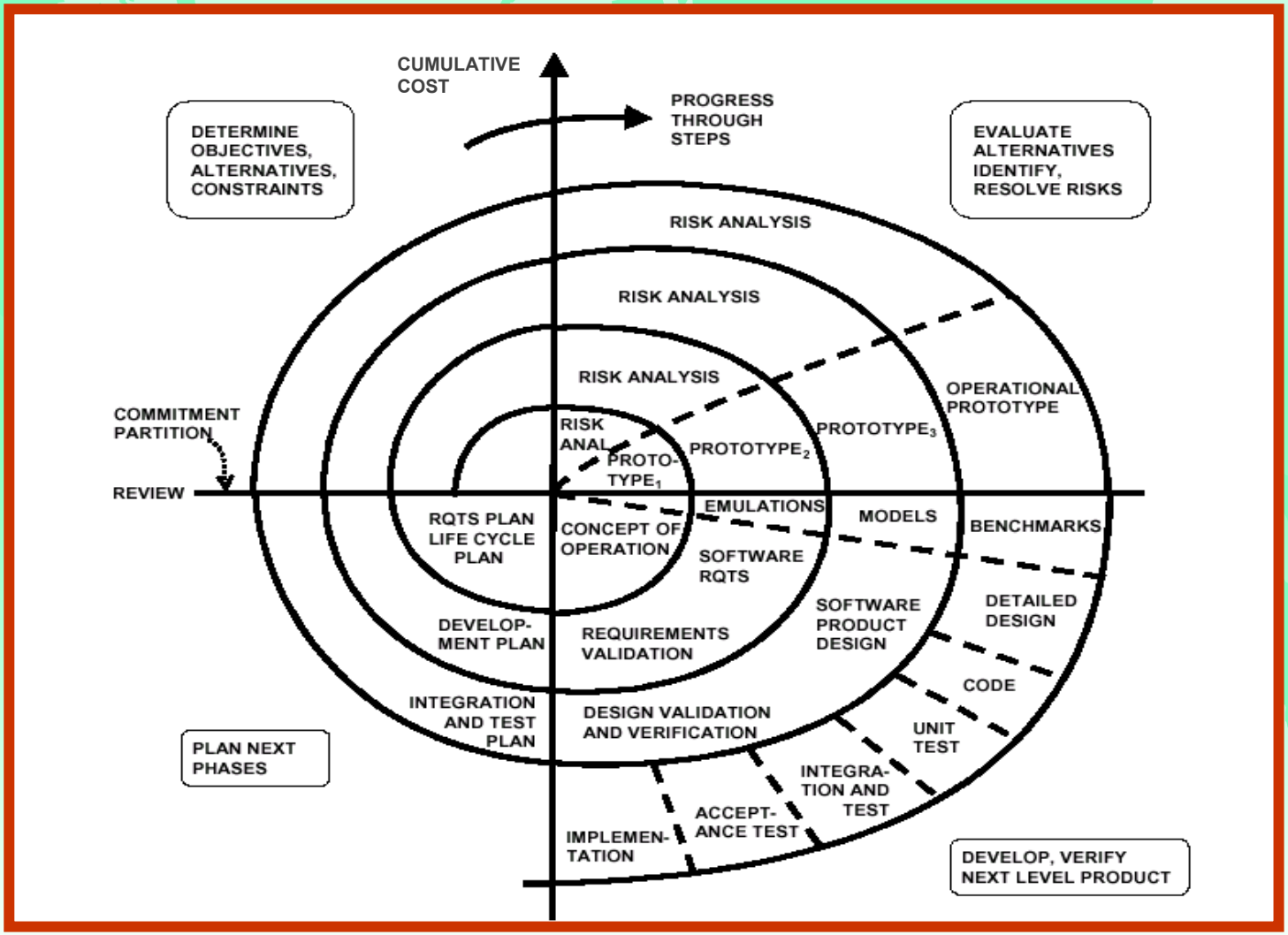
Our Role

- We are in a business of developing and validating advanced ATM concepts
- We face a difficult question of what, when, where, and how different studies need to be conducted
- The scope and level of study varies from concept to concept
- Often iterative process - build a little, demonstrate a little, test a little, and implement a little…..
- We often face resource constraints (budget, skills, people..)
- Often we need to make decisions about what is the right method and when to adopt it?

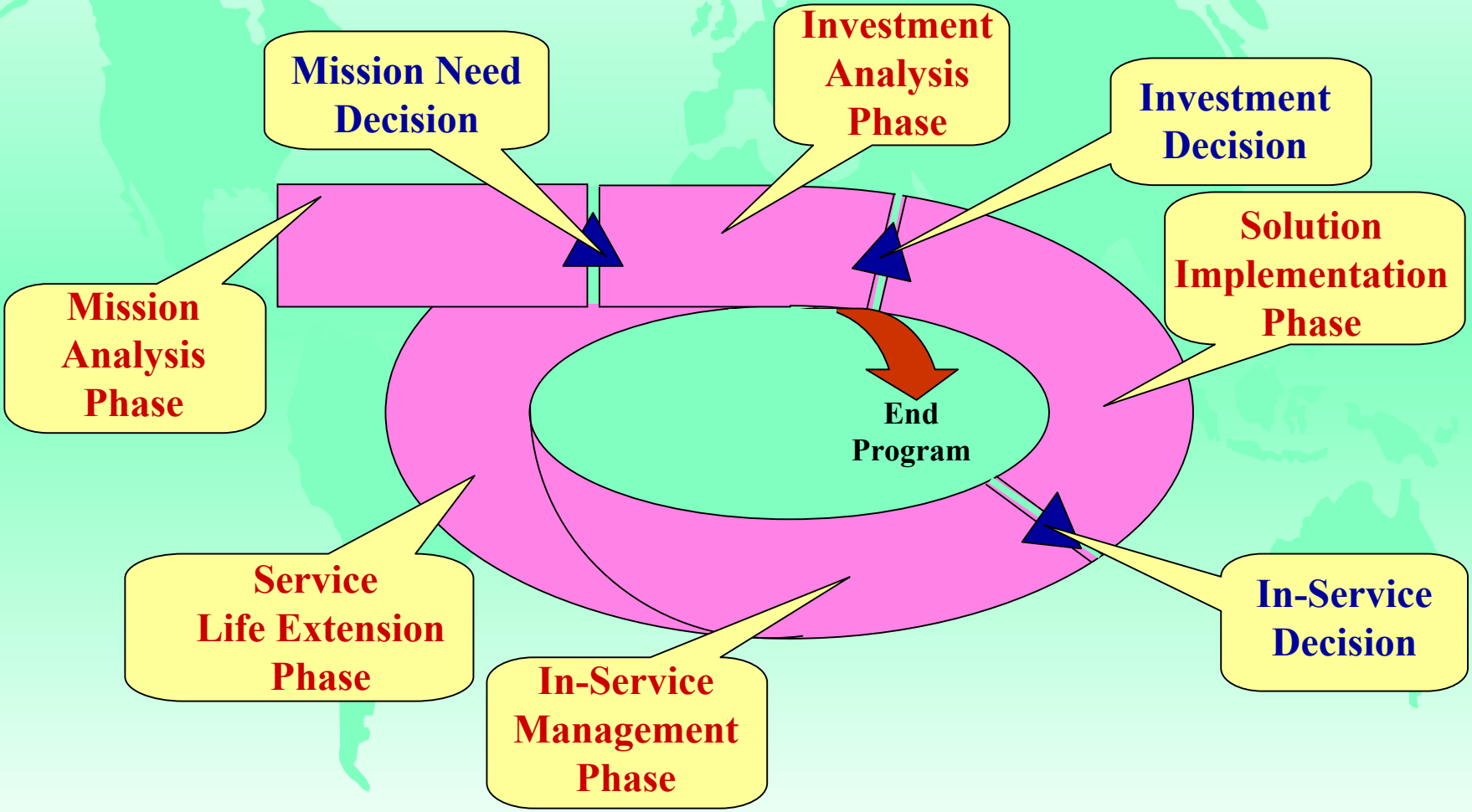
Banana Model - Activities



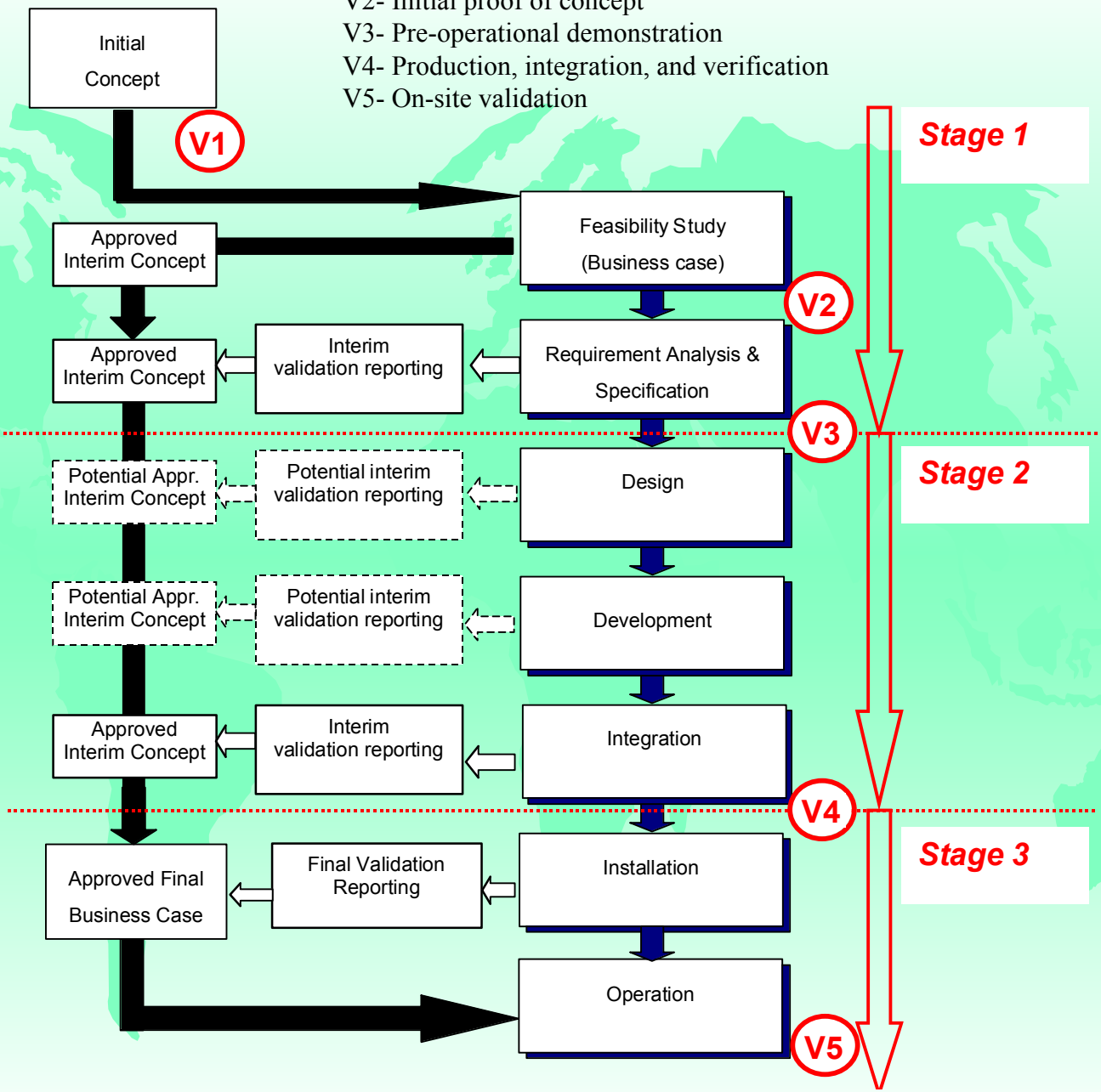
Spiral model– Build a little, Test a little



FAA Acquisition Management System



V1- Concept development
V2- Initial proof of concept
V3- Pre-operational demonstration
V4- Production, integration, and verification
V5- On-site validation



Scenario Definition

- An outline or model of a set of events planned to excite system and/or human performance and their interaction with the aim of examining their resulting behavior

Potential Disconnect

- FT M&S and RT two sides of the VALIDATION coin
- Different skills are required for RT and FT M&S
- Requires considerable understanding of each technique
- Validation phase(s) could be different
- FT is done when research is often not complete
- A lot of assumptions are necessary for FT M&S
  - Procedures (e.g., CPDLC- manual, automated, hemispheric rules, etc.)
  - Roles and responsibilities (e.g., division of labor between planner and executive or R and D-side controllers)
  - Difficult to capture human performance impact (e.g., workload) in the FT
  - Need to make system wide simulations (i.e., one or two SMEs may not be representative)
- RT simulations have to make some assumptions about technology, concepts, CHI, etc.
- Often we are resource constrained to go back and refine FT M&S studies based on results of RT

Connection between RT and FT M&S

FT M&S To RT

- Situations creating largest benefits
  - Different roles and responsibilities, DST automation, concepts where feasibility studies can be focused
- Risk analysis
- Safety analysis
- Narrows the scope for RT

RT/HF To FT M&S

- Specific human performance data
- Task analysis
- Roles and responsibilities
- Operational procedures
- Calibrate FT M&S models
- Validation of FT M&S results
- User acceptance

RT and FT M&S Coordination - Examples

- Reduced Vertical Separation Minima
  - Benefits: flexibility and capacity – maximum number of aircraft in a sector, potential conflicts, etc.
  - Human performance, display concepts, and procedures
  - Changes in monitor alert parameter (MAP) value/sector capacity
  - Simulation parameters: mix equipage, altitude assignment, etc.

- Investment decisions (e.g., CPDLC)
  - Human communications performance data and associated workload
  - Individual differences in transfer of control and transfer of communications

RT and FT M&S Coordination - Examples

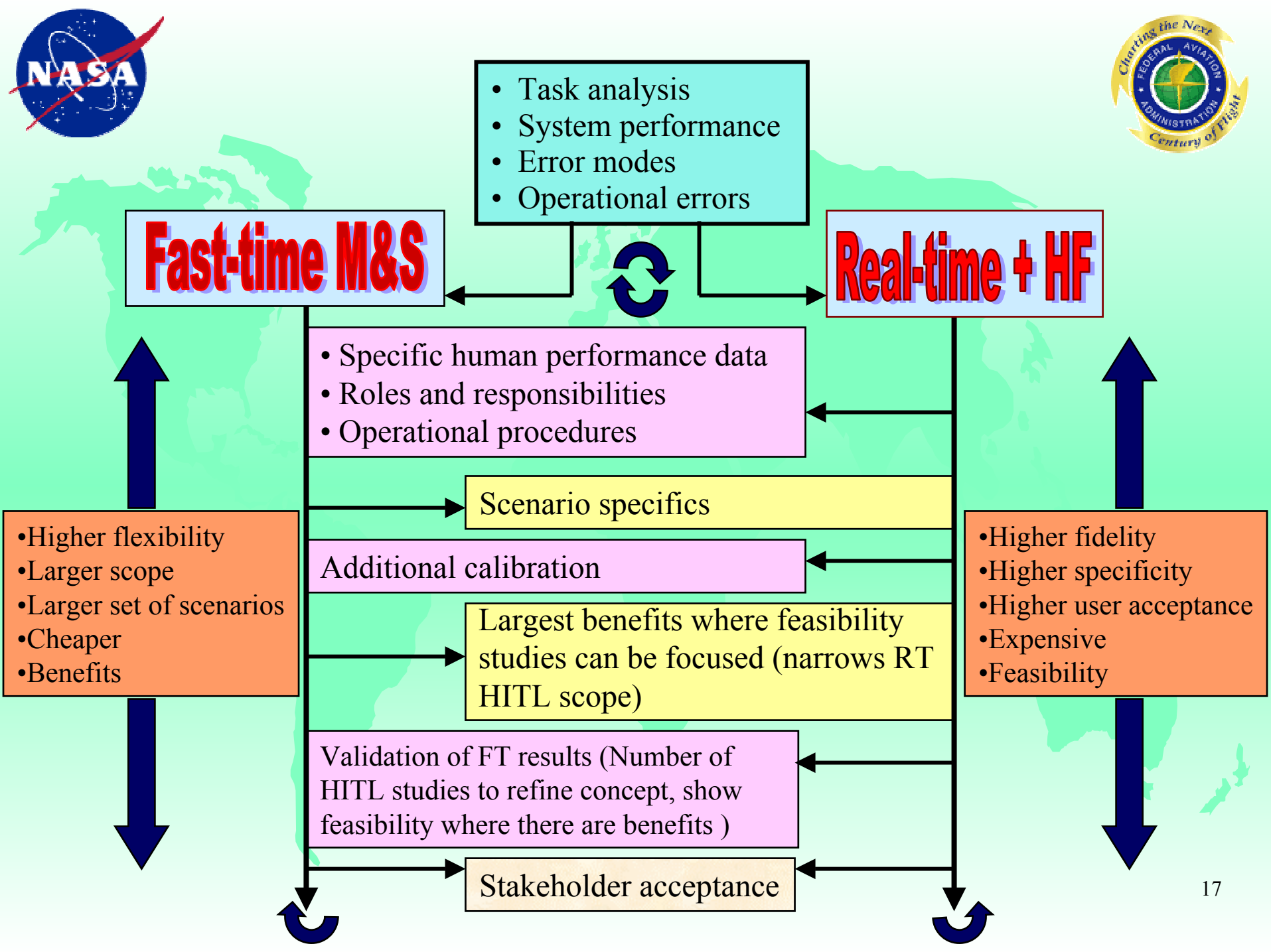
- Conflict detection and resolution (CD&R) algorithms
  - Role of FT M&S:
    - Examine CD&R performance data (missed alerts, false alarms, hits, and correct rejections)
    - Examine effect of CD&R parameters (conflict detection threshold probability, look-ahead time, resolution maneuvers)
  - Role of RT: Examine user acceptance, trust, and perception of missed alerts, false alarms, hits, and correct rejection
  - Scenarios: Need an extensive catalogue of conflict situations
  - Need considerable operational data related to errors in trajectory prediction, flight dynamics, and aircraft performance characteristics
  - Quite challenging process yet very critical from safety and benefits perspective
  - Scenarios for FT M&S and RT need to be compatible/similar in conflict characteristics
  - How do we develop scenarios that will ensure the desired number of potential conflicts, conflict geometries, conflict locations, etc. (e.g., time-shifting of trajectories using genetic algorithms)

RT and FT M&S Coordination - Examples

- Exploring Time-based metering (TBM)
  - Currently, distance based traffic flow management is widely used
  - Hypothesis is TBM would offer greater accuracy and efficiency
  - Benefits assessment using FT M&S (errors in conformance/task performance in advanced concepts are hard to judge)
  - Feasibility (challenge- switch to TBM from distance-based paradigm)
  - Scenario implications: Need human performance data from RT for FT M&S for benefits assessments
  - Considerable scenario development related to traffic, software, adaptation, and CHI

FT M&S and RT Coordination - Examples

- Distributed Air-Ground Traffic Management
  - Using the "right" baseline to assess the impact of DAG-TM concept elements (e.g. Free Maneuvering)
  - FT M&S needs to consider the demand forecast in target year (e.g., 2015)
  - FT needs to consider not just the current operations, but anticipated DSTs just prior to DAG-TM
  - FT M&S needs to consider human performance aspects, roles, and responsibilities, etc.
  - RT needs to consider the forecast, advanced DSTs, their CHI, etc.
  - Scenarios need to be developed to accommodate forecast to excite the feasibility, safety, and benefits


• Task analysis
• System performance
• Error modes
• Operational errors
Fast-time M&S
Real-time + HF
• Specific human performance data
• Roles and responsibilities
• Operational procedures
Scenario specifics
Additional calibration
Largest benefits where feasibility studies can be focused (narrows RT HITL scope)
Validation of FT results (Number of HITL studies to refine concept, show feasibility where there are benefits)
Stakeholder acceptance
•Higher flexibility
•Larger scope
•Larger set of scenarios
•Cheaper
•Benefits
•Higher fidelity
•Higher specificity
•Higher user acceptance
•Expensive
•Feasibility

Ideas for Guidelines

- A RT and FT M&S expert needs to be added in each study work group (at least review is necessary)
- Assumptions need to be explicitly addressed
  - Functional decomposition, roles, and responsibilities, etc.
- Need standard characteristics of scenarios – nominal, off-nominal, traffic density forecast for target years, flow-upsetting events
  - Levels of weather, type of weather, and impact of weather

Ideas for Guidelines

- Need mature human performance models/process
  - Current HPM techniques/software include:
    - Reorganized ATM Mathematical System (RAMS),
    - Performance Usability Modeling and Assessment (PUMA),
    - The Man-Machine Integration Design and Analysis Simulation (MIDAS), and
    - Micro saint
- Monte Carlo simulations
- Customized software (e.g., time based traffic management)

Ideas for Guidelines
Data Bank for both RT M&S and HT

- Human and system related performance data bank is necessary (may be VDR can include that)
  - System performance, response time (e.g, CPDLC), and variability data
  - Human error modes (likely human errors – what does FT need to include?)
  - Trajectory prediction inaccuracy, and aircraft position inaccuracy
  - Battery of flow-upsetting parameters/events
  - Traffic forecast for target years
  - Baseline (DSTs, traffic, airspace, procedures, roles and responsibilities, operators, etc.)
- Standardized scenario characterization is necessary (traffic, conflicts, forecast, etc.)
- Let's start it!

Some Challenges

- Often user task times are not available for advanced concepts or DSTs
  - CHI is not completed, procedures are not defined, and we need to make a lot of assumptions
  - Baseline is not clear (DSTs, airspace, etc.)
    - Often new wine in old bottle, or old wine in new bottle!
  - Budget, resources, and schedule may not permit extensive iterative RT-FT coordination

Suggestions for FT M&S (Where RT and HF data is useful)

- Use storyboarding, task analysis, cognitive walkthrough, and part-task studies early on
- Use available performance data
- If CHI, roles, and responsibility information is available then a part-task study can be conducted to get required data
- If budget and time does not permit studies, use heuristic estimates (e.g., GOMS)
- SME input to collect task allocation, time estimates (last resort, don't try to use it first, certainly not just one SME)

Suggestions for RT (Where FT M&S data could be useful)

- FT M&S can be used to do a sensitivity analysis on division of labor between executive and planner (or R and D-side)
  - Example, free maneuvering concept – consider nominal value and sensitivity range to assess benefits
- Higher benefit options can be further explored by RT to assess feasibility

Optimization

- Optimization: Methods and their uses
  - FT M&S is a great method
  - Scenario development using optimization techniques
    - Genetic algorithms using time-shifting trajectories
    - Wind-optimized routes
    - Optimized airspace and airspace redesign to take advantage of GPS, RNAV, and ADS-B
    - Optimal roles and responsibilities between dispatchers, flight crew, and air traffic controllers for better distribution of workload
  - Linear, integer, and dynamic programming; statistical optimization; genetic algorithms; neural networks; simulated annealing; etc.
  - Consideration to inaccuracies and errors is challenging

Conclusions

- FT M&S and RT coordination is essential
- Iterative process
- Need to start developing data banks for human and system performance, roles, and responsibilities, etc.
- Develop a standard HPM approach
- Share new methods, lessons learned, and data via VDR

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Topic 1 – Discussion

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- DFS Deutsche Flugsicherung GmBH

Discussion Topics

- Challenges in developing scenario requirements for FT M&S of advanced concepts
- Challenges in developing scenarios for FT M&S of advanced concepts
- Level of coordination between FT M&S and RT
  - Baseline, Traffic forecast, R&R, Functional decomposition, etc.
- Human performance modeling
- Optimization
- Data bank – how can we get there?
- Other topics