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# RTSP and ATM/CNS Performance Modeling

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Advanced Air Traffic Management  
Applied Statistics

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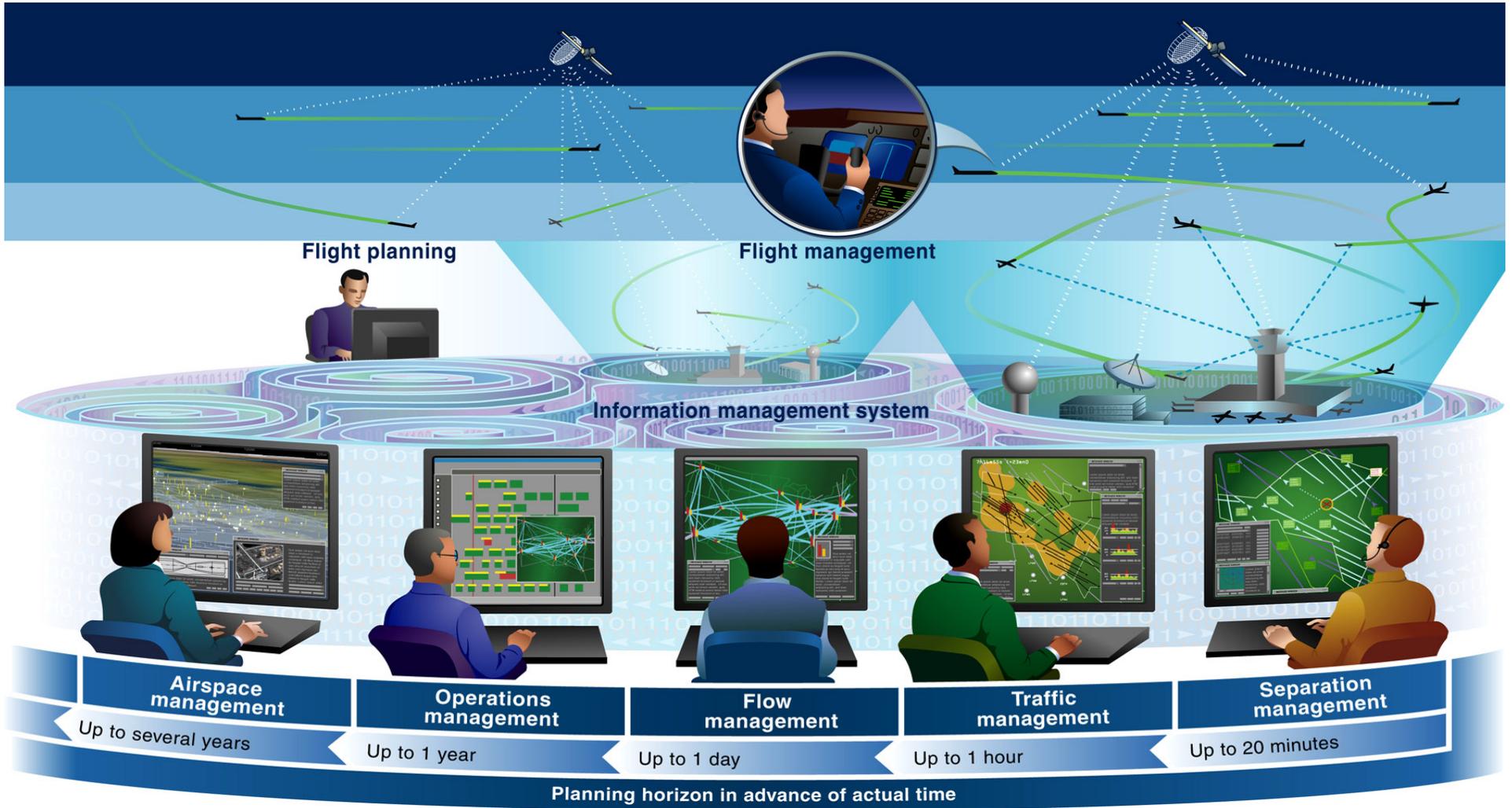
# Agenda

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- **ATM/CNS ICAO Performance Hierarchy and RTSP**
- **What may RTSP be?**
- **Some questions concerning ADS-B and RTSP performance modeling**
- **System Dynamics (Vensim), RTSP modeling objectives, and preliminary ADS-B modeling structure**

# Air Traffic Management Services

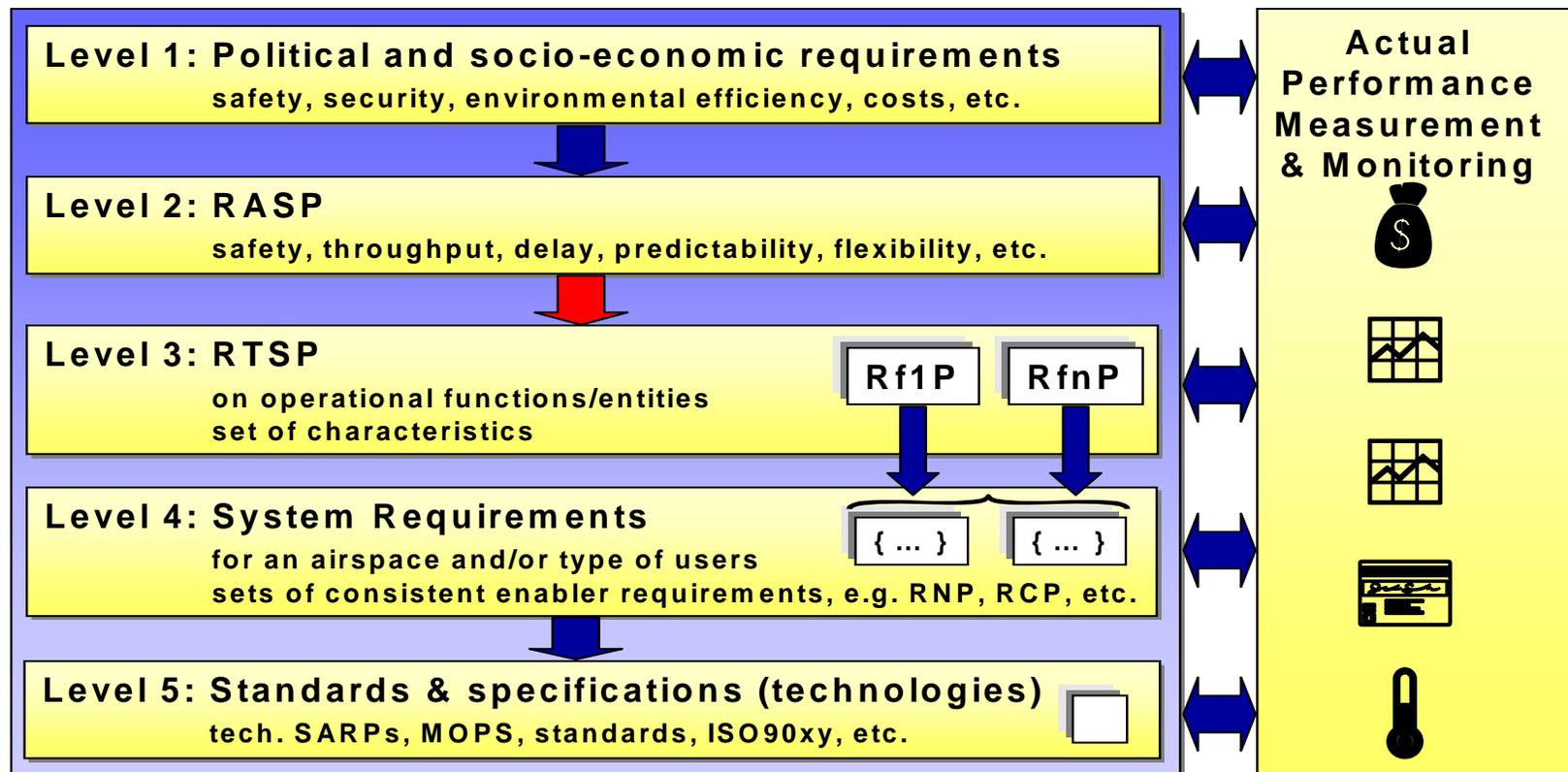
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# RTSP and 5-level ATM Performance Hierarchy

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## Hierarchical ATM Performance Concepts



\*Air Traffic Management operational concept panel (ATMCP), Meeting of the working group of the whole,  
Tenth Meeting, Seville, Spain 27 January to 7 February 2003

# A Performance Framework to Structure Discussion – ANC 11 September 2003

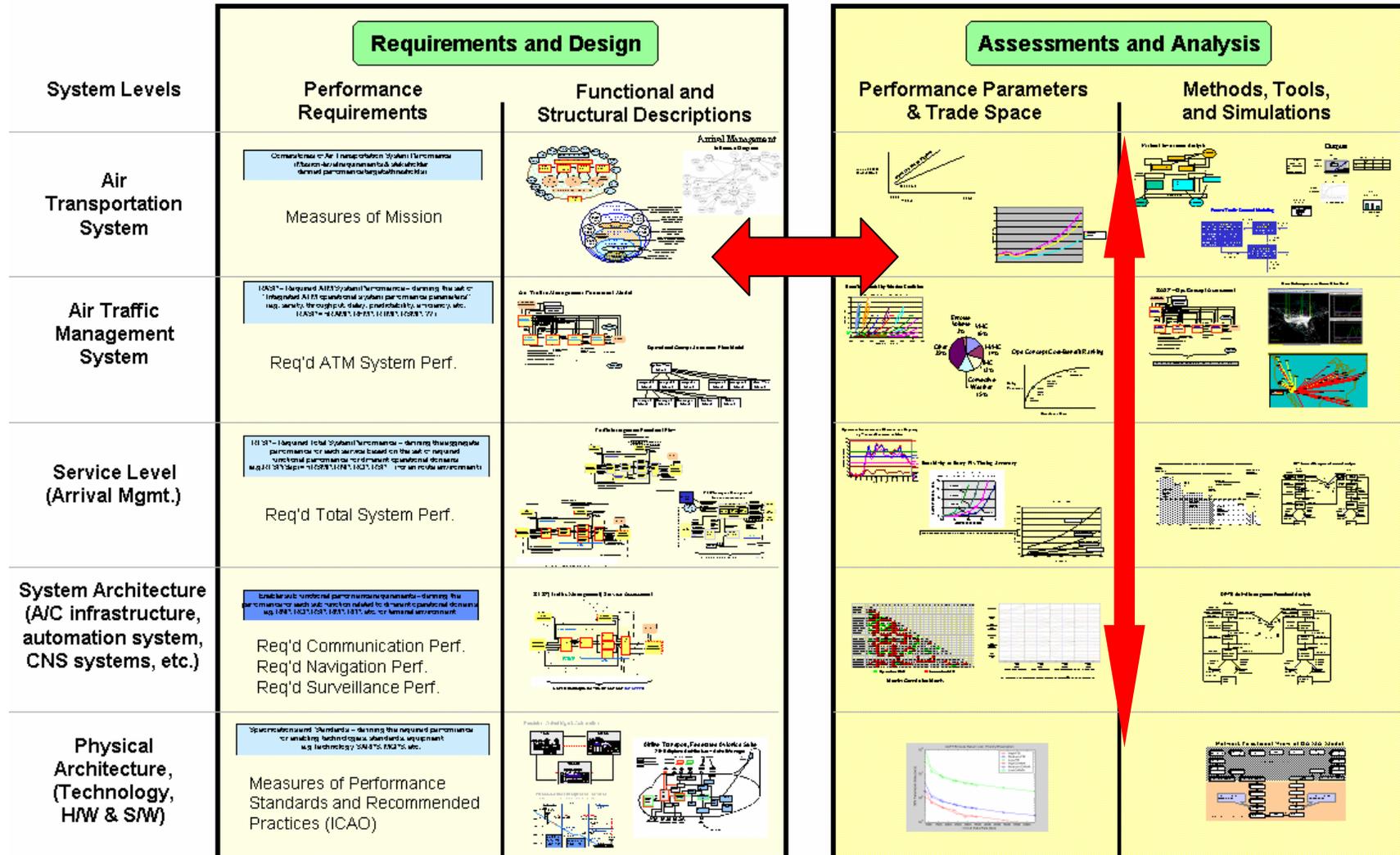
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- **Three pillars**
  - A **hierarchy** of ATM Performance Concepts
  - Accurate models of **'what drives what'**
    - e.g. cause/effect relationships between expectations, functions, system components, concept of use, architecture
  - Rigorous description of **traceable** performance parameters
    - An approach: ISO13236 Quality of Service Framework

# ATM 5-Level Hierarchy & Arrival Management

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## Case Study Assessment Framework



# ICAO OCD 11 Key Performance Areas

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1. **Access and Equity**
2. **Capacity**
3. **Cost Effectiveness**
4. **Efficiency**
5. **Environment**
6. **Flexibility**
7. **Global Interoperability**
8. **Participation by the ATM Community**
9. **Predictability**
10. **Safety**
11. **Security**

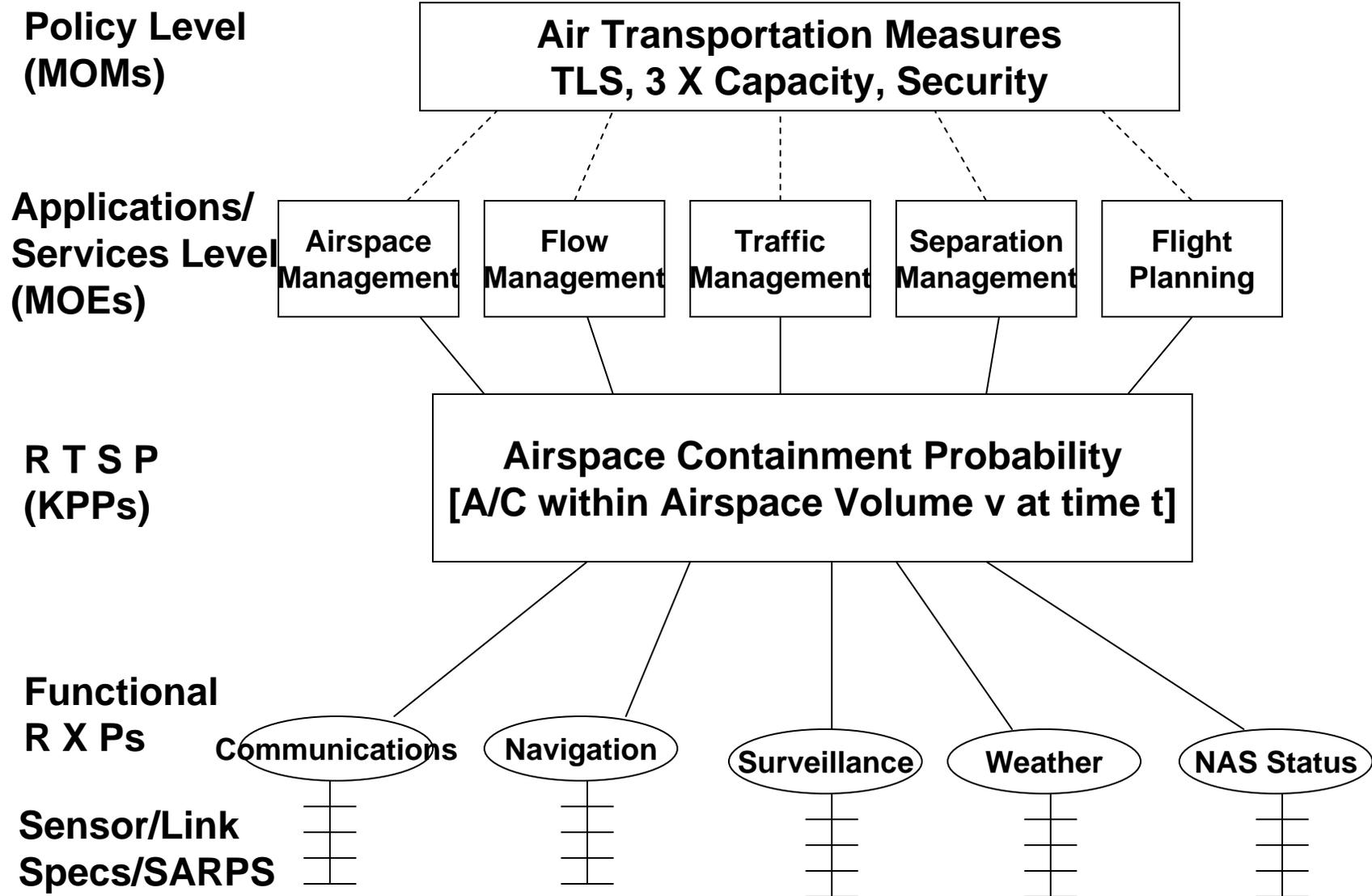
# What may RTSP be?

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- **Aggregate performance measure of 'total' ATM system?**
  - $RTSP = f(RCP, RNP, RSP, \dots RWP \dots RXP)$ ?
  - ATM/CNS Conops – ICAO doc. 9854 7 so-called concept components (e.g. demand/capacity balancing, traffic synchronization,...)
- **Is there a primary operational-related measure for RTSP within ICAO 11 KPA (Key Performance Area)?**
  - Propose 'predictability' KPA as primary measure
  - Predictability as a function of look-ahead time (e. g. 4DT) in certain airspace volume (e.g. RTSP as probabilistic 'success' metric ~ 99.9 for separation management with 20 min. look-ahead time - LAT)
- **Predictability should not be confused with estimation**
  - RNP, conformance monitoring, and 4DT prediction
  - For any ATM service delivered:  $RTSP(\text{index}) = RTSP(\text{LAT})/RTSP(\text{LAT} = 0)$

# RTSP and ICAO Five Level Performance Hierarchy

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# System Dynamics (Vensim™)RTSP and ADS-B Modeling Objectives and Preliminary Structure

# Levels of Abstraction for M&S

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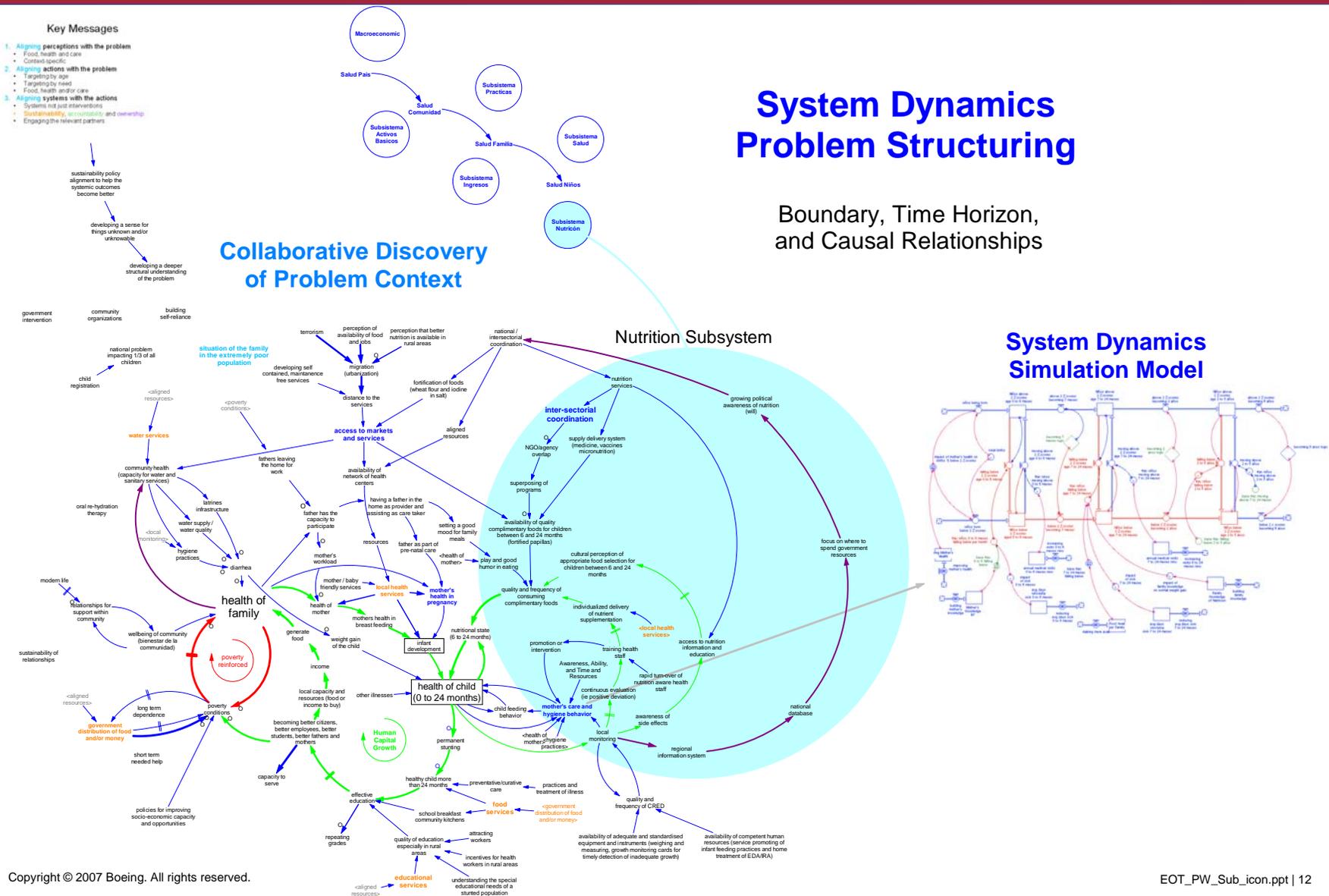
Method	Types of Questions to Investigate	Typical Results
<b>PowerPoint Engineering</b>	<p><u>What will sell and get \$\$ in the POM?</u>            What looks good with lightning bolts?            How many buzzwords can we synergistically leverage in a value-added way?</p>	<p>Pre-determined solutions            Impossible Architectures</p>
<b>System Dynamics Models</b>	<p><u>Why does the system behave this way?</u>            Why do changes in one part of the system have an effect on another part of the system?            What if projects have a lot of uncertainty?            Why doesn't adding staff fix the schedule?</p>	<p>System level trends            Identification of the relevant factors  <u>Insight into effects due to altering influence</u></p>
<b>Process Models</b>	<p><u>What is the latency?</u>            What is the queue wait time?            What is the mission timeline?            What is the right number of resources?            Where do bottlenecks form?</p>	<p>Timeline measures (seconds, minutes, etc)            Throughput measures (bit/sec, bombs dropped/hr, etc)            Resource utilization measures            Queue length measures  <u>Insights into effects due to changing parameters</u></p>
<b>Physics-based Models</b>	<p><u>How far can the radar see?</u>            How much fuel can it carry?            How accurate is the weapon?            What is the cost per seat mile?</p>	<p><u>System performance prediction</u></p>

# Example of a System Dynamics Model

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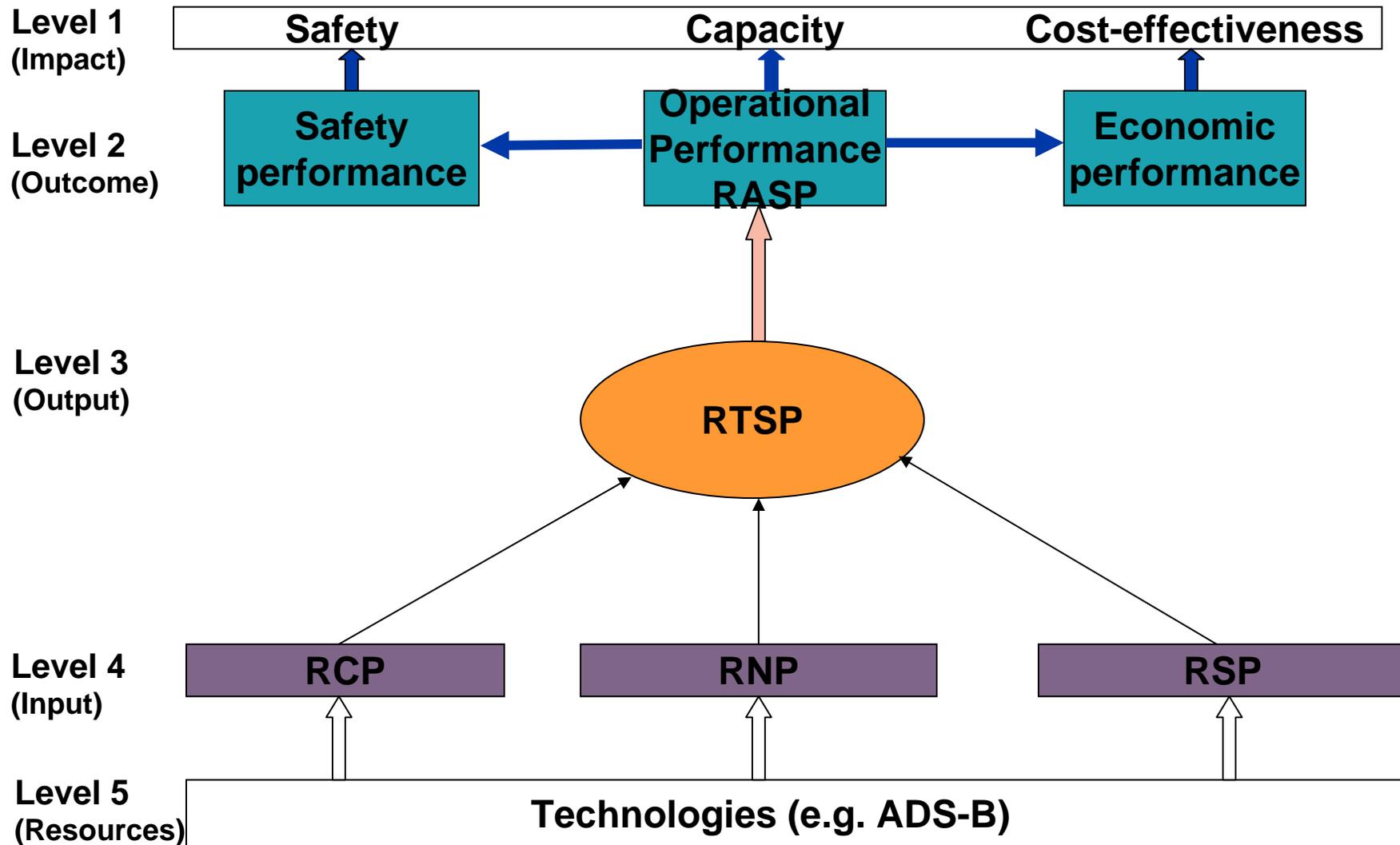
## System Dynamics Problem Structuring

Boundary, Time Horizon, and Causal Relationships



# ATM 5-Level Hierarchy - Simplified

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# Some Questions Concerning ADS-B and RTSP Performance Modeling

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- Are ‘pure’ RNP operations sufficient as a performance mode precluding the need for RSP, in general, and ADS-B, in particular? (Navigation vs surveillance...)?
- What are possible C, N, S allocation combinations with ADS-B in GOMEX and beyond?
- What are the relationships between ATM service benefits delivered and infrastructural costs accrued with ADS-B?
- How do we trace and link technology enabler performance ‘below’ to ATM service provision ‘above’ within the 5-level performance hierarchy? What would be examples of concrete models?

# General Modeling Objectives

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- Integrate the results of other studies without the need to create a comprehensive (and perhaps unmanageable) model
- Understand dependencies between key performance measures and parameters
- Understand feedback and time lags
- Understand fluctuations, feedback, lags
- Use these synthetic models as vehicles for communication and cooperation between experts

# Performance Modeling with VENSIM – ADS-B

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- Example of VENSIM Modeling
- Set-up simplified ADS-B (out) performance framework
  - 5 level RTSP hierarchy/heterarchy
  - Construct an operational concept ADS-B performance model
  - Define integrative performance framework between levels
  - Define integrative performance modeling framework (Vensim)
  - Show higher level to lower level influences and linkages
  - Show key performance metrics for each hierarchical/heterarchical level relationships
  - Represent C, N, and S performance relationship outcomes and impacts
    - Represent cost/benefit performance relationships between infrastructure implementation costs (level 5) and operational benefits (level 2)

# “Intermediate” System Dynamics ADS-B Modeling

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- Neither minute details nor coarse summaries
  - Trajectories
    - Described probabilistically by their aggregate “deviations from normality”, not by their dynamics
  - Actions: controllers, pilots
    - Described probabilistically by their *likely* consequences
  - Communication –
    - Described by delay distribution, errors...
  - Traffic
    - Described by high level characteristics
      - Complexity, rates, throughput....
- Integrate in our models, at higher level of abstraction
  - Adopt and adapt results from detailed models
  - General wisdom and empirical knowledge
  - Causal knowledge
  - Data about likely deviations, timing, dependencies...

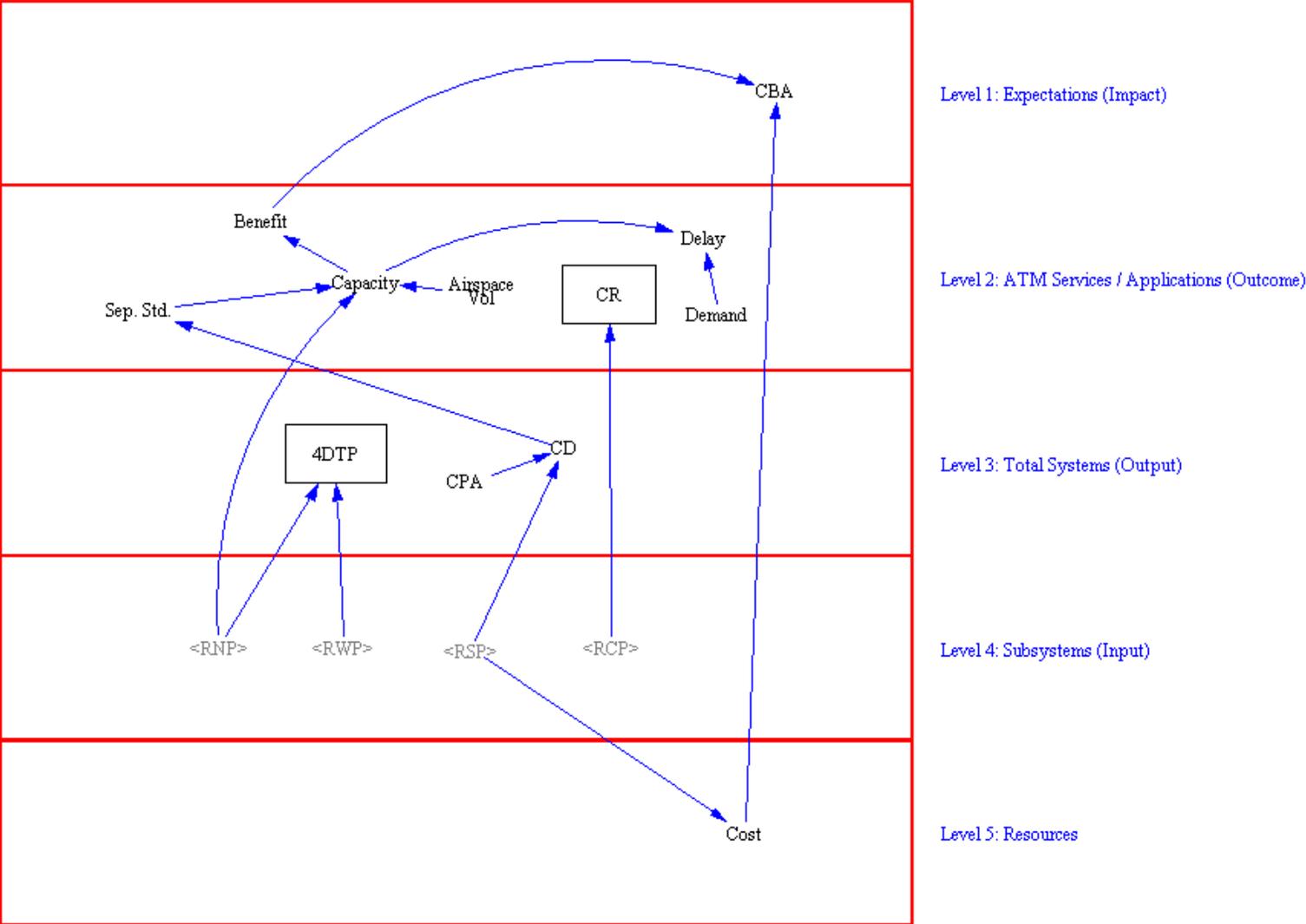
# Key Parameters and Variables

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- Look ahead times
- Separation standards
- CPA
- RCP
- RNP
- RSP
- Traffic complexity characterized by some high level measures
  - Encounter geometry, traffic density, etc

# Overall Initial Vensim Diagram

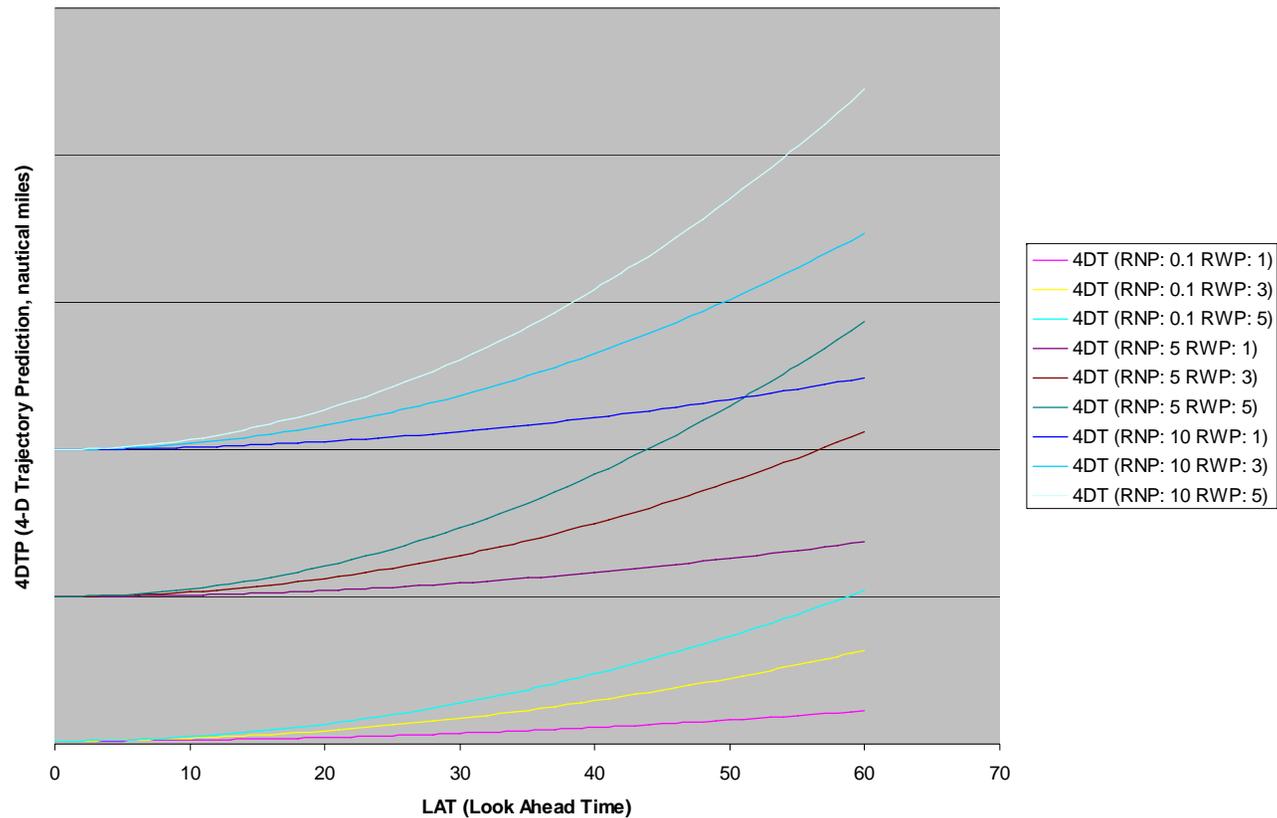
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# 4D Trajectory Prediction Uncertainty vs. LAT

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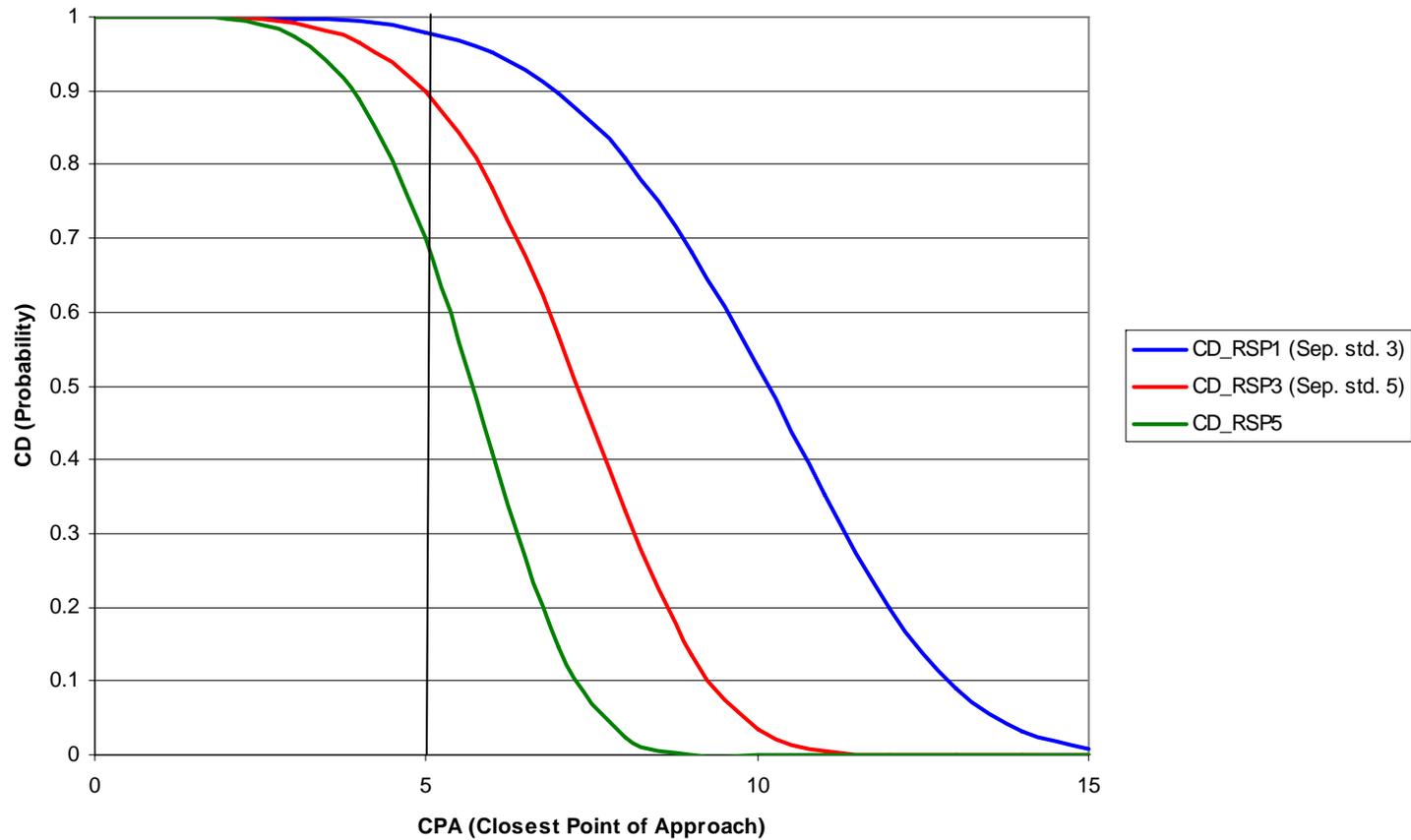
4DTP vs LAT (as function of RNP and RWP)



# Conflict Detection vs. CPA

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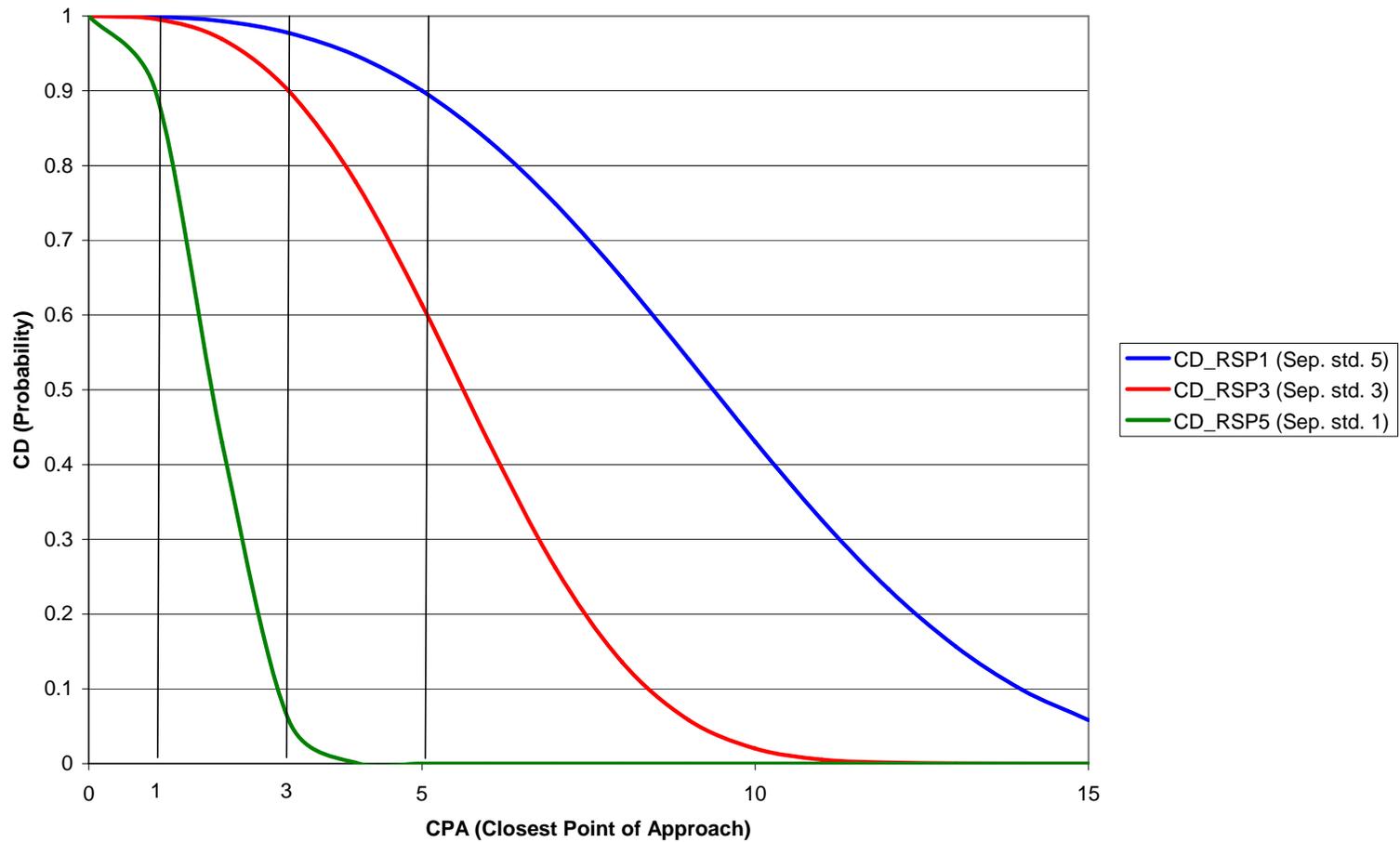
Conflict Detection vs. CPA



# Conflict Detection vs. CPA

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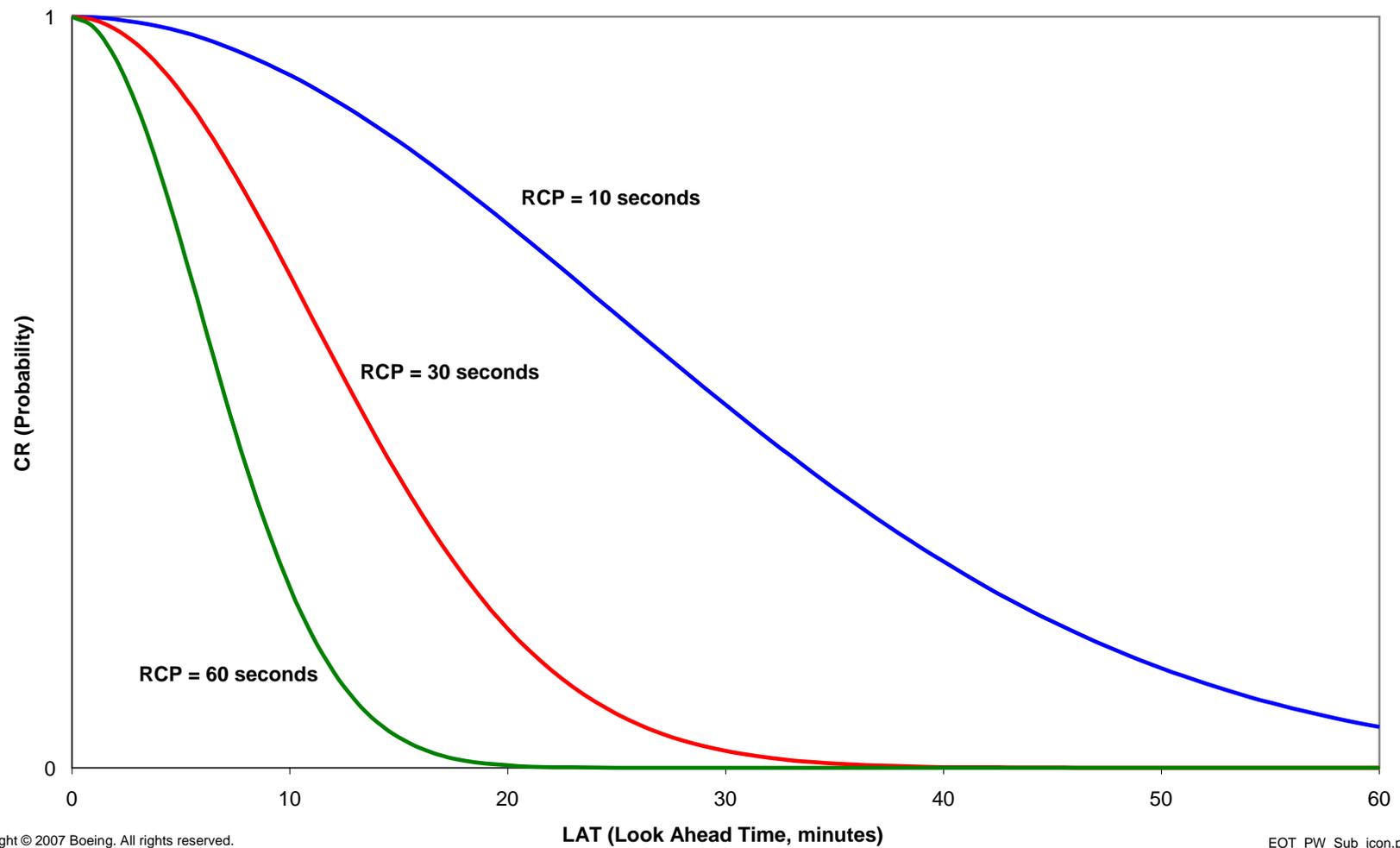
Conflict Detection vs. CPA



# Conflict Resolution vs. LAT

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Conflict Resolution vs. Look Ahead Time as function of RCP



# Next Steps

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- **Infuse current model with additional ‘realism’**
- **Construct scenarios to test model scope and range**
- **Map results of operational performance modeling to economic/investment analysis**
- **Identify modeling-related ‘lessons learned’ for application to other ATM/CNS conceptual elements (e.g. CBE, GATI...)**

