Keynote Presentation:

Enabling Elegant Systems Design Through Technical Storytelling in Virtual Worlds

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Outline

- Motivation
- Elegant Systems Challenge
- Key Enablers and Approach
  - Experiential Perspective
  - Technical Storytelling
  - Virtual Worlds
- Illustrative Study
- Takeaways

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Motivation

- Systems becoming increasingly more **complex**
- System modeling and simulation key to understanding complex systems
- System modeling languages unsuitable for non-engineers
- Need new ways to engage **ALL stakeholders**
- Need to quantify **elegance** of resulting system design

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Mike Griffin's Refrain (2010)

"…. **lacking quantitative means** and effective analytical methods to deal with the various attributes of **design elegance,** the development of successful complex systems is today largely dependent upon the **intuitive skills** of good systems engineers."

Elegant System Definition

An **aesthetically appealing, engaging** and **affordable** (and open) system that offers **requisite functionality** and **predictable responses** with **minimum structural complexity**.

- - Azad M. Madni, 2013

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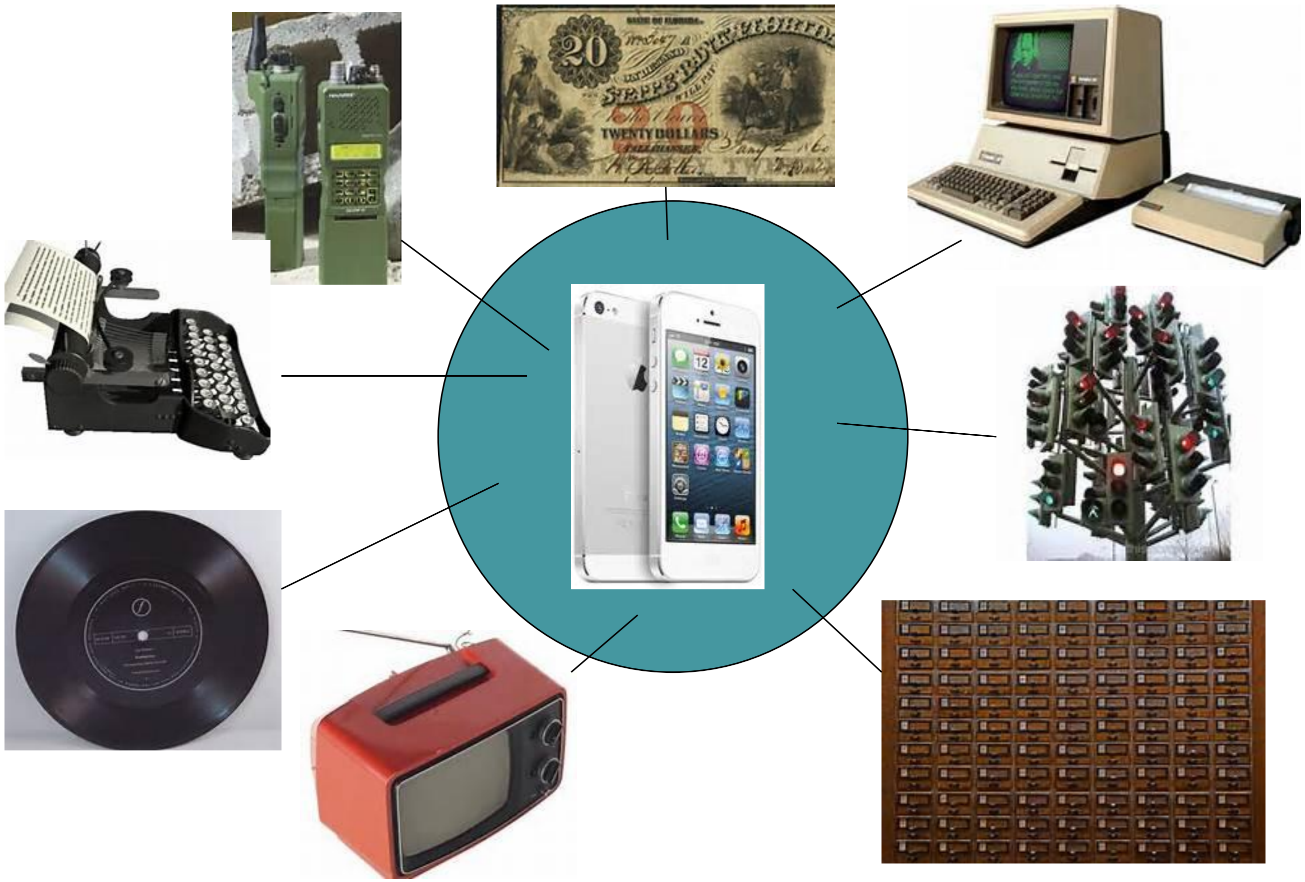
An Elegant System



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Elegant Design (Quantitative View)

Design that offers required functionality with minimum structural complexity. It is cost-effective and exhibits predictable behavior.

Madni, A. M., 2014

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Experiential Perspective

- Exploit intuitively **appealing abstractions** and **metaphors**
  - non-engineers can understand and contribute
- Foster **effective interaction** with **ALL** stakeholders
- Expanded role of systems engineer
  - **creator of experiences** that address stakeholder concerns
  - conditions/cues introduced during system modeling and design to shape stakeholder experiences
- Design placed within its **operational / usage context**
  - **technical stories** can unfold in virtual worlds creating insightful experiences for **ALL** stakeholders

Exemplar metaphors

- Structural metaphor
  - when one concept is structured as another
- Orientational metaphor
  - pertains to structuring experiences in terms of spatial directions
- Ontological metaphor
  - helps structure experiences of abstract phenomenon in terms of concrete objects and forces

“Experiencing” System Design

- **Interact with system** in virtual worlds (multiple contexts)
- Use built-in points in technical story **to explore system behavior**
- **Explore sensitivity** of system behavior to parameter changes
- Develop **feel for system size** (relative dimensions)
- View **comparisons** of structure, behavior, appearance, costs, risks
- Use **embedded cues**, **hyperboles**, **color codes, sounds,** and **3D animations** to focus on specific aspects of system structure/behavior
- Understand **constraint violations** (color codes, sound alerts)
- Use **pause-resume, branching** and **playback** at key points (technical or human event) in technical story to examine system behavior

Experiential Perspective Adds to Design Elegance

- Adding an experiential perspective will help ensure **greater stakeholder participation**…..
- ……..which ensures superior coverage of requirements especially in **upfront engineering** …….
- ……..which contributes to elegance in system architecture
- ……..which contributes to **design elegance.**

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Experiential Perspective Impact

- Allows **ALL stakeholders** to:
  - interact with system and observe system behaviors without having to learn engineering notation
  - contribute to collaborative design especially during upfront systems engineering
- **Illuminate system interactions** previously not known or identified during system modeling through **immersive experiences** in virtual world

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Technical Storytelling

- Two interpretations:
  - use of technology to tell stories
  - **tell stories about technical systems (Madni, 2014)**
- Approach:
  - place system being engineered at the center of technical story
  - use stories to impart technical knowledge about system to stakeholders
  - allow stakeholder to interact with and understand system
  - interactions shape system behavior and influence technical story

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Virtual Worlds

- **Immersive** 3D multimedia simulation environments
- Key characteristics: **persistence**; continue to exist after users exit; user-made changes also remain
- Ideally suited for **interactive** technical storytelling
- **Non-technical stakeholders** understand system structure and behavior by interacting with system within story environment
- Can be realized through **game engines** such as Unity 3D
- Can be **instrumented** to collect pertinent data for evaluation and comparative analysis

Illustrative Study: Aircraft Divert Scenario

- **Problem:** airplane takes off, experiences a malfunction
- **Decision:** divert / not divert airplane
- **Options:** airplane equipped / not equipped with Aircraft Health Management (AHM) system
- **Scenarios:** sunny day, rainy day
- **Hypothesis:** With AHM, airplane will experience fewer diverts
  - up-to-the-minute aircraft **health** and available **landing sites** info
- **Shortcoming:** full value of AHM not always realized
  - several stakeholders unfamiliar with AHM usage
- **Solution:** allow ALL stakeholders to “experience” AHM within technical stories in virtual worlds

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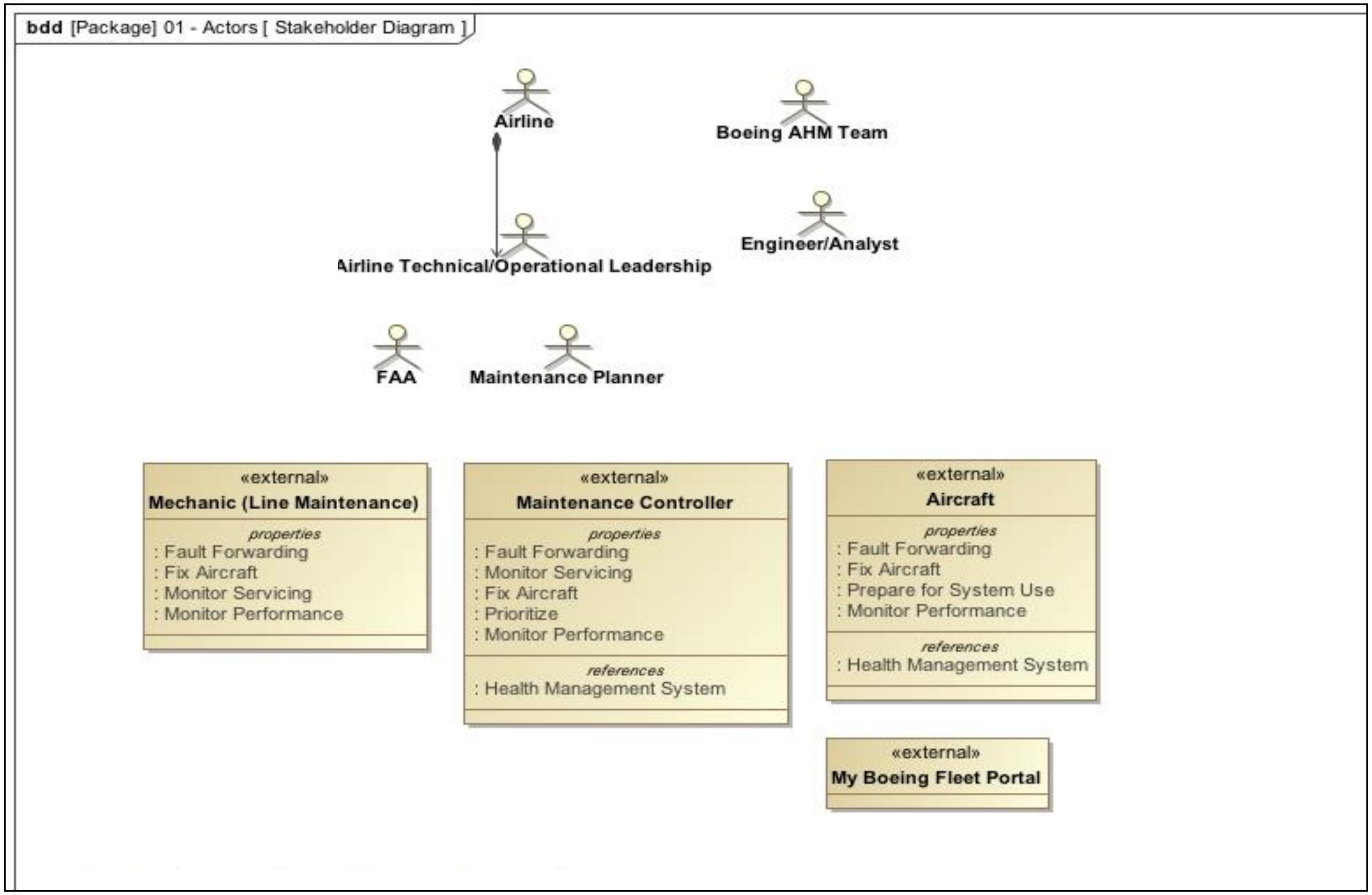
Technical Storytelling-based Approach

- **Technical stories** constructed around system
  - e.g., Aircraft Health Management (AHM) system
- System modeling **inputs**
  - operational scenarios / use case diagrams
  - operational business process / activity diagrams
- **Mapping** system models to storytelling space
- **Story execution** and **data collection** in virtual worlds
  - role-specific / function-specific **lenses** to examine design
  - user-system **interaction** to experience design
  - **system model refinement** based on stakeholders' feedback

Stakeholder Diagram: Actors



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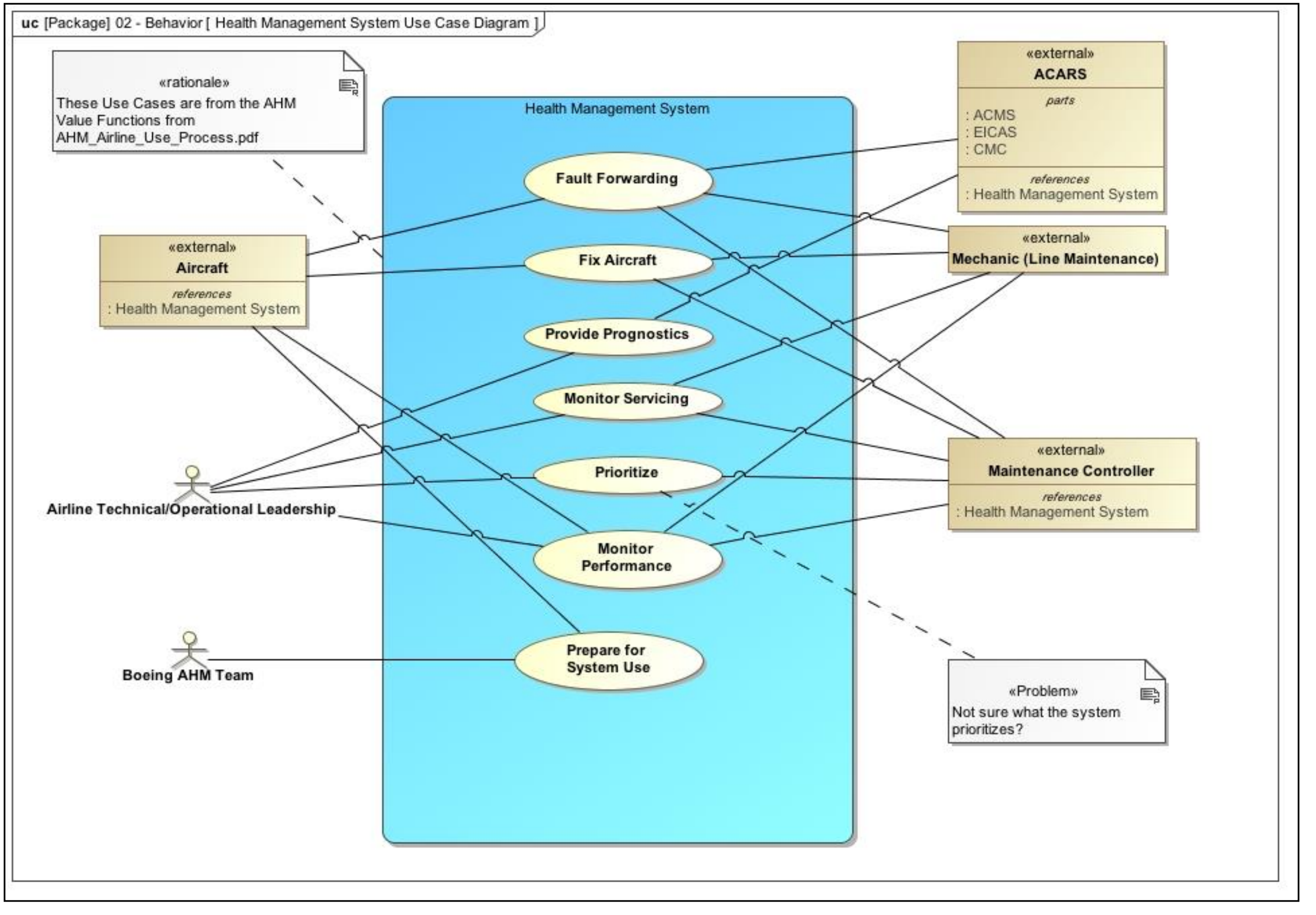
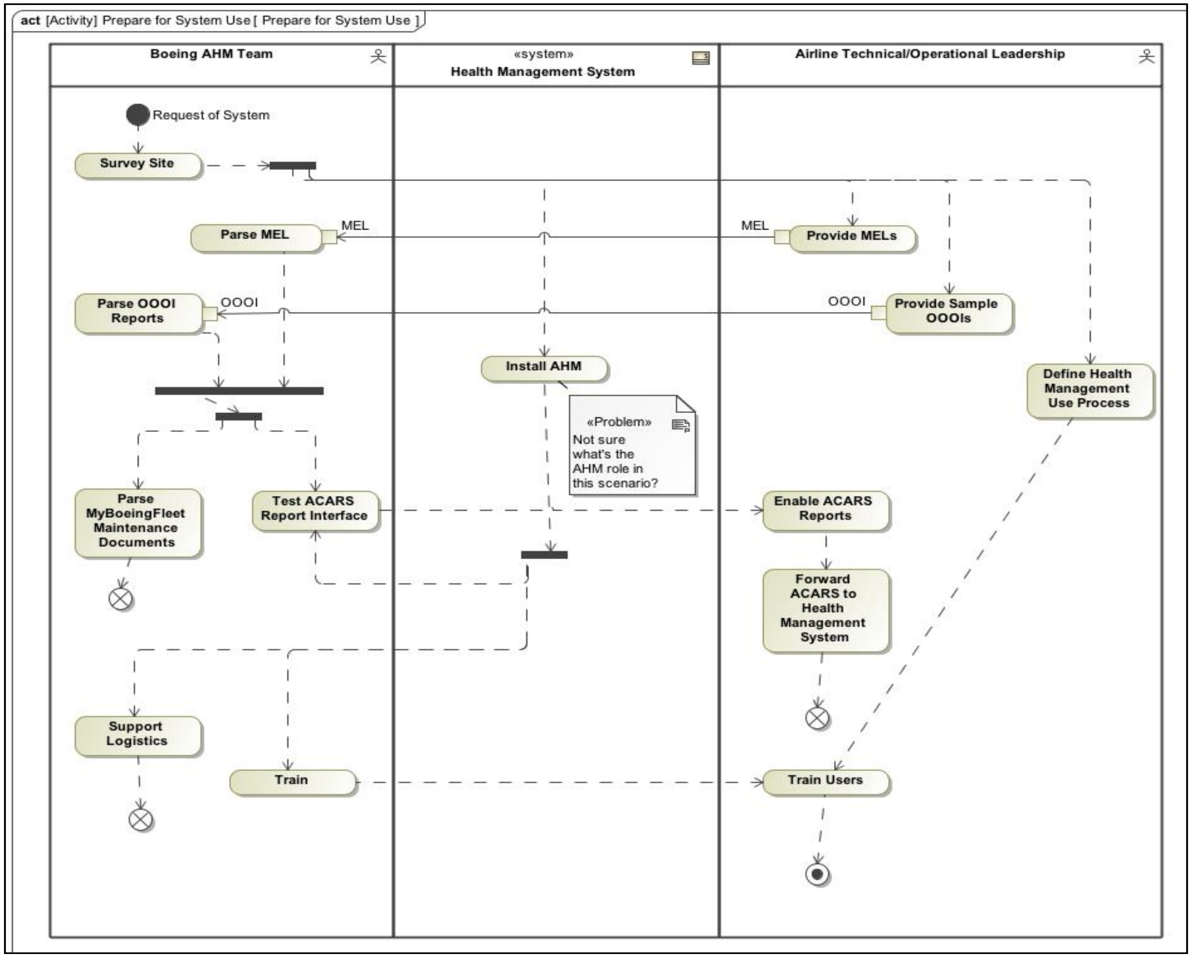
Behavior Diagram:
Health Management System Use Case



Activity Diagram: Prepare for System Use



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Mapping System Model to Virtual Worlds

SYSTEM MODEL (Design Space)	VIRTUAL WORLD (Storytelling Space)
Structural and Behavioral Views	**Structure and Behavior** (system behavior emerges as subsystems interact with each other, and system interacts with story characters; collective interactions alter technical story trajectory and potentially mission outcomes)
Use Case(s) and Activity Sequence Diagrams	**Technical Story** (how system is used, by whom, and under what conditions; contextualizes use case(s) and sequence diagrams; allows stakeholders to collaborate and provide feedback on needed system changes)
Humans and Roles	**Technical Story Characters** (story participants, or story narrator, SMEs; interact with system as story unfolds; have personalities and preferences that influence their interaction with system
Viewpoints	**Stakeholder Lenses** (author-defined; eventually constructed on demand)
Basic Flow of Events	**Main Storyline** (defines events, characters, and interactions between and among them)
Alternate Flow of Events	**Vignettes** (multiple clusters of interactions among specific characters who interact with the system as story unfolds)
Exception Flow of Events	**Surprise Vignettes** (represent twists in technical storyline and/or unexpected or surprising ending resulting from what-if changes to system properties and resulting system behavior; illuminate system resilience to unanticipated/emergent conditions)
User-System Interactions	**Character interactions** (define which characters interact with the system, and how under different contexts)
Task Prerequisites/ Dependencies	**Character Task Performance Requirements** (information that system needs to provide to characters to perform tasks)
System Composition and Human Interaction	**Extended Family Tree** (defines how subsystems relate to each other and to the characters in the story)

Collaborative Experience within Virtual Worlds

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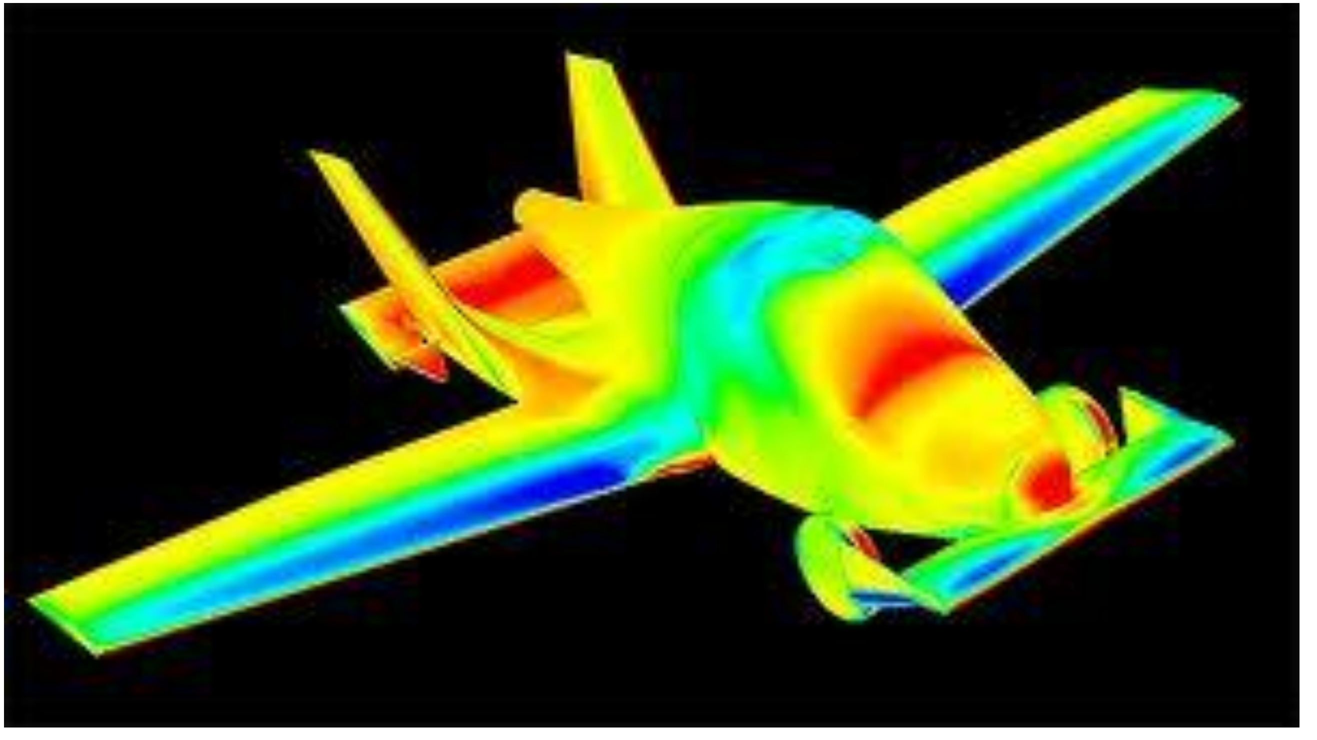
Communicating Hotspots



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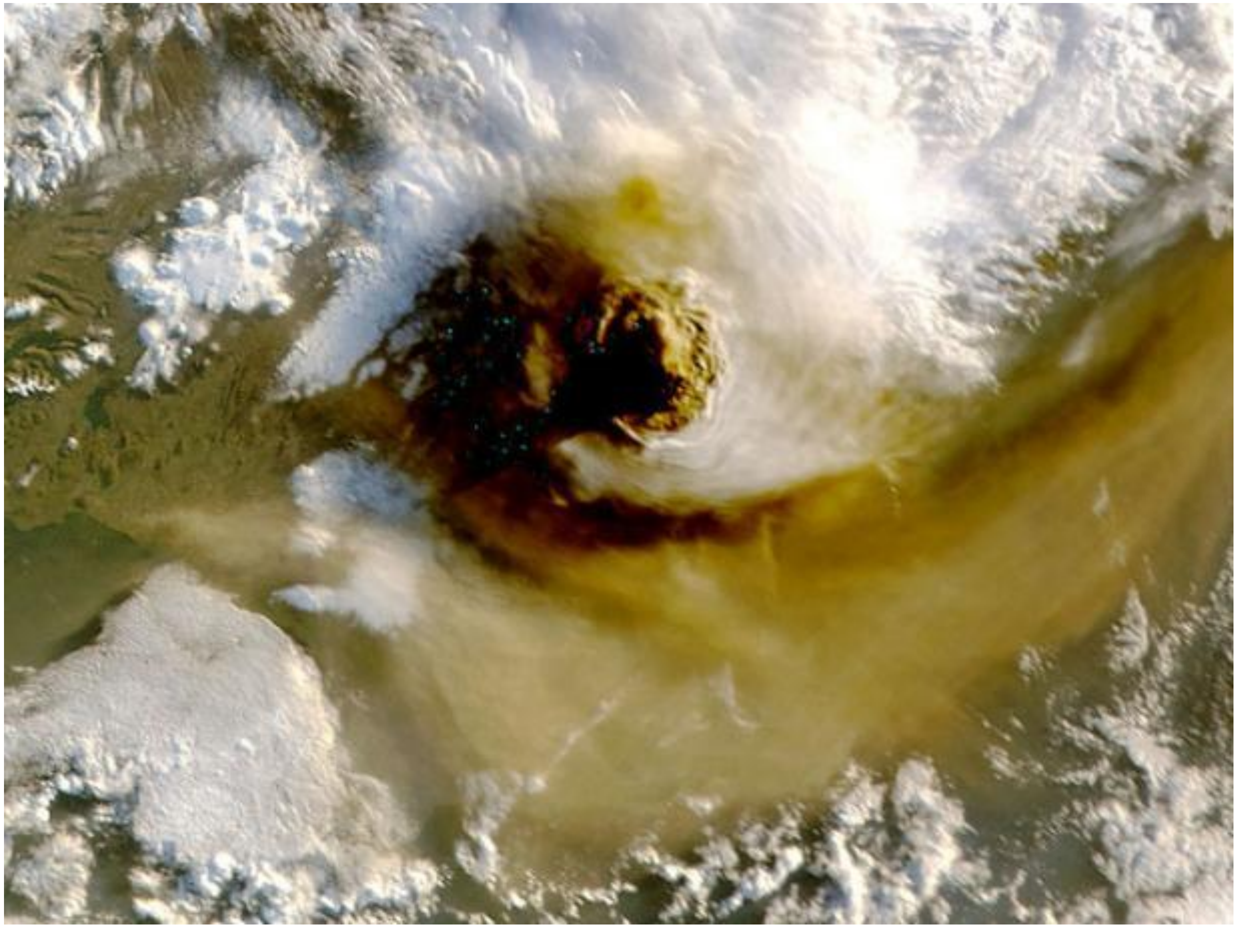
Conveying Relative Dimensions

A Disruption….



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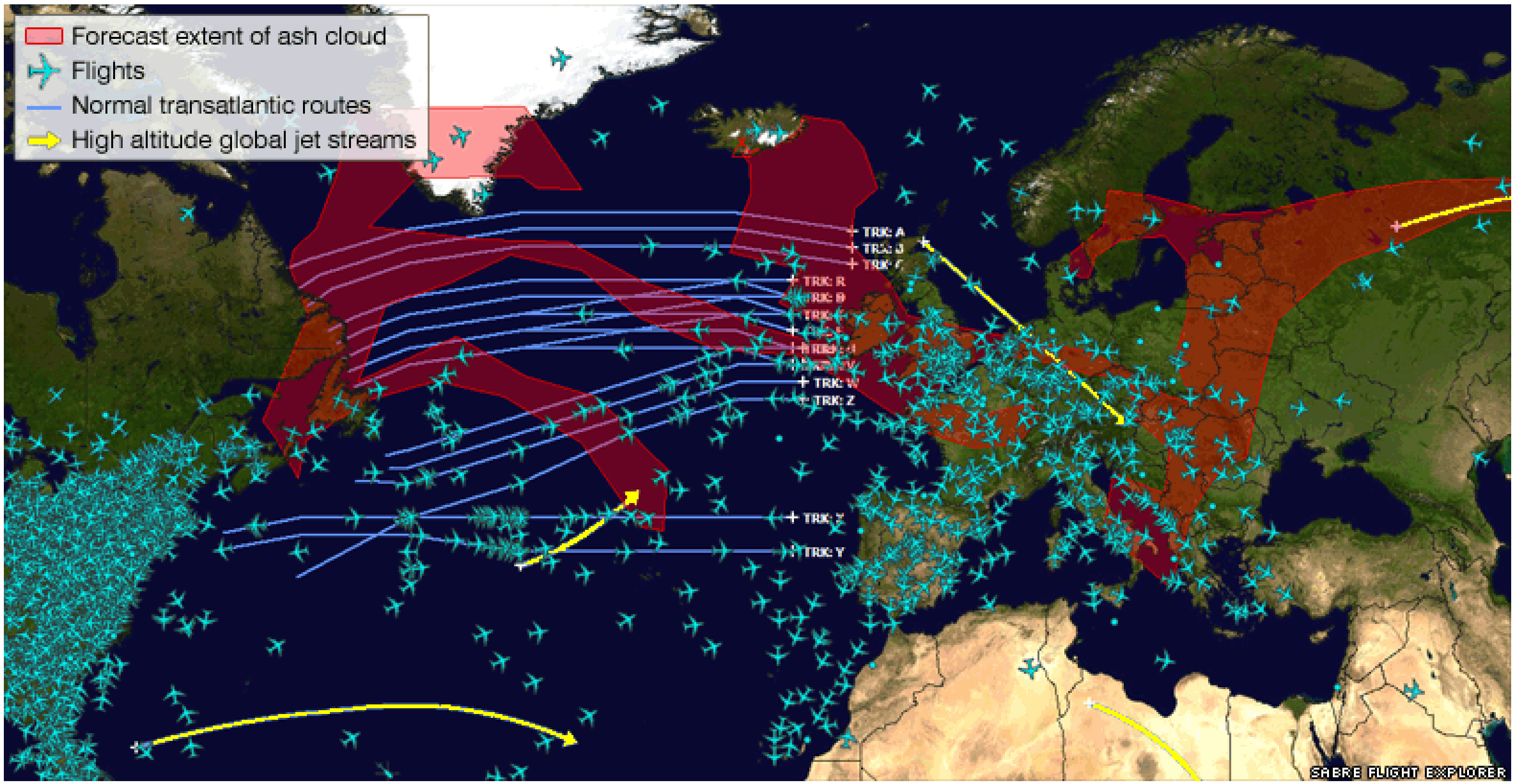
….That Leads to Diverted Flight and Timeline Adaptation



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Exemplar Metrics

- Stakeholder-related
  - # stakeholder recommendations accepted (model update, end product)
  - increase in # stakeholders providing inputs
  - increase in # inputs per stakeholder
- System model-related
  - # model updates resulting from experiential perspective
  - increase in system elegance (i.e., reduction in structural complexity)
- Process-related
  - reduction in model rework / extraneous iterations
  - Increase in process elegance (i.e., reduction in process complexity)

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Takeaways

- **Complexity, especially non-systemic complexity, can often be reduced** up to a point beyond which system begins to **lose flexibility**
- Elegant system design offers **rich functionality** with **minimum structural complexity**
- **Experiential perspective** is an **enabler** of elegant system design
- Experiential perspective can be brought to life through **technical stories**
- **Virtual worlds** offer a cost-effective platform for technical storytelling
- Technical storytelling is about **system usage** and **behavior** in operational settings
- **Game engines** such as Unity 3D are a convenient platform for rapid, cost-effective construction of virtual worlds
- Experiential perspective is key to **engaging ALL stakeholders** in upfront engineering (collect comprehensive requirements and constraints)
- Sound **upfront engineering** avoids costly rework / extraneous iterations
- **Structural complexity** is a quantitative metric for assessing system elegance

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- Technical Director, Systems Architecting and Engineering Program
- Founder and CEO, Intelligent Systems Technology Inc.
- Elected Fellow of AAAS, AIAA, IEEE (Life), IETE (Life), INCOSE, SDPS
- Ph.D., M.S., B.S. in Engineering, UCLA
- **2014 INCOSE Lifetime Achievement Award**
- **2013 IIE Innovation in Curriculum Award**
- **2012 INCOSE-LA Exceptional Achievement Award**
- **2011 INCOSE Pioneer Award**
- 2008 SDPS President's Award
- 2006 SDPS C.V. Ramamoorthy Distinguished Scholar Award
- 2004 DARPA IPTO *Sustained Excellence by a Performer* and *Significant Technical Achievement* Awards
- 2000 and 2004 Developer of the Year Award (Software Council of SoCal)
- 1999 SBA's National Tibbetts Award for California
- Past President of Society for Design and Process Science (2006-2008)
- **IEEE SMCS Technical Committee Co-Chair for MBSE**
- **Research Interests: complex engineered systems, model-based engineering, engineered resilient systems, technical storytelling/games**

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