A Robust, Scalable Transportation System Concept

2005 RSCA Kick-off Briefing

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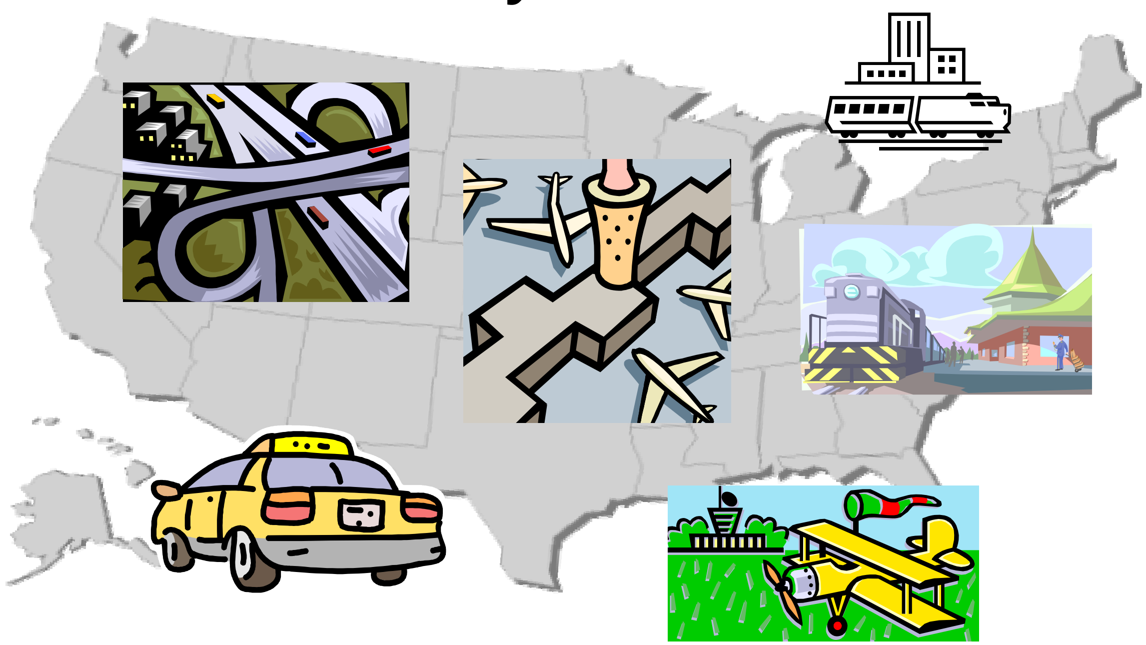

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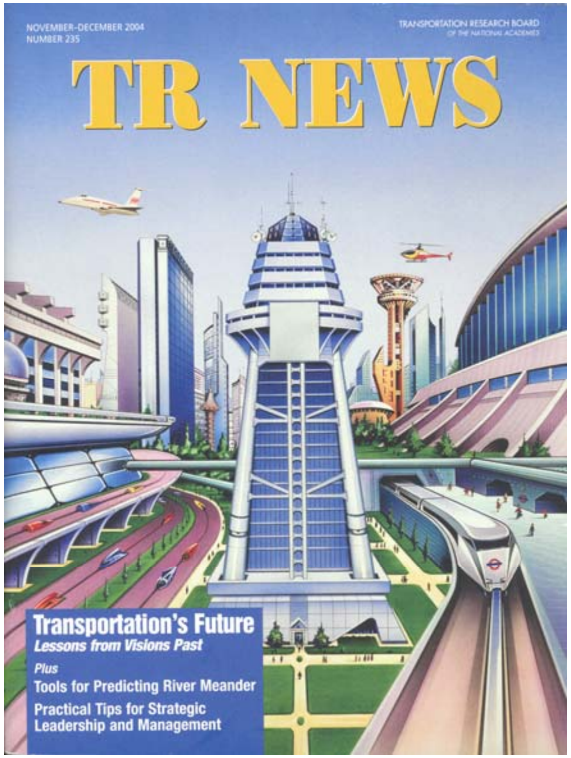
Why, What, and How:

The Problem & Proposed Concept

- ***Today's System***
  - *Limited growth in utility*
  - *Non-scalable and brittle*
  - *Marginal response to traveler needs*
- ***Intermediate Concepts***
  - *Still under today's tech limits*
  - *Incremental improvements in <u>individual</u> systems*
  - *"The Whole" is less than the sum of the parts?*
- ***Revolutionary ~~System~~ System-of-Systems Concept***
  - *Higher-level, integrated transportation concept*
  - *Goals: Increases in . . .*
    - *Throughput & Accessibility*
    - *Robustness & Natural adaptation*
  - *But: there is no master architect*



<u>How?: Generate Desired Transportation Sys-of-Sys's</u>

Within sets of rules of an agent-based simulation, observe what mix of vehicles (air/ground), airspace networks, infrastructure, business strategies, and policies emerge as the agents seek to achieve the desired transportation traits ("new NAS").

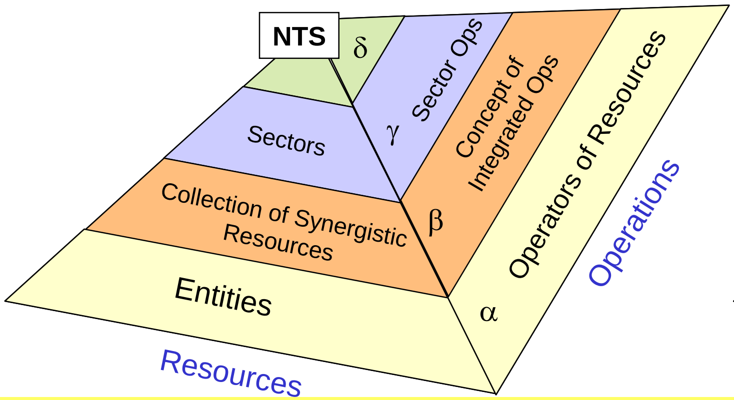
Scope, Assumptions, & Knowledge

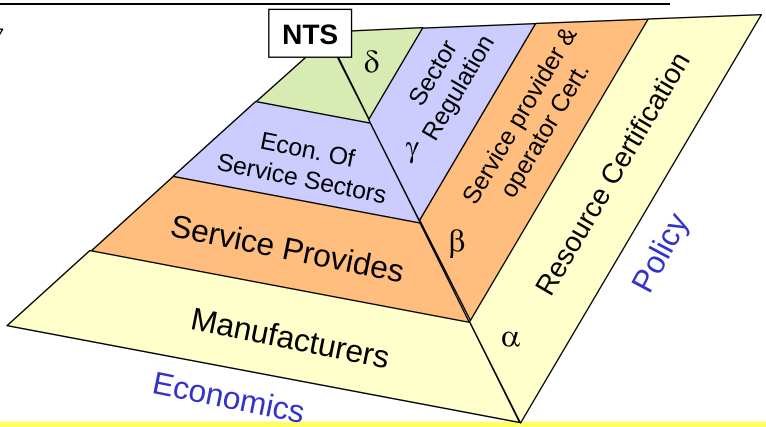
- Scope:
  - – Given cost, schedule, and purpose, simulation/concepts will be high-level
    - VAMS/ACES, etc. study lower level concepts & objectives with high fidelity
  - – Understanding transportation concepts as Sys-of-Sys's will be emphasized
- Assumptions
  - – "Clean Sheet" study approach, meaning we will:
    - Allow innovative system concepts, but . . .
    - Not ignore realities like: legacy of current systems, market imperatives, etc.
- Knowns and Unknowns
  - – Knowns
    - E.g. 95% of Cargo/People moved on Ground/Water, 5% by Air (BTS)
    - Transportation capital for "new NAS" will be shared with other modes of travel.
  - – Known unknowns
    - E.g. Rate of growth/decline of economy; time to build in new technologies
    - Seek: Thresholds to overcome barriers (make improvement sensitivities known)
  - – Unknown unknowns
    - E.g. The technology, policy, or disruption that will make the system invalid
    - Seek: Insight that turns these to known unknowns

Our Study Language

Categories	Descriptions
Resources	The entities (systems) that give physical manifestation to the system-of-systems
Economics	The non-physical entities (stakeholders) that give intent to the SoS operation
Operations	The application of intent to direct the activity of physical & non-physical entities
Policies	The external forcing functions that impact the operation of physical & non-physical entities

Levels	Descriptions
Alpha (α)	The base level of entities, for which further decomposition will not take place. α-level components can be thought of as building blocks.
Beta (β)	Collections of α-level systems, organized in a network.
Gamma (γ)	Collections of β-level systems organized in a network.
Delta (δ)	Collections of γ-level systems organized in a network.



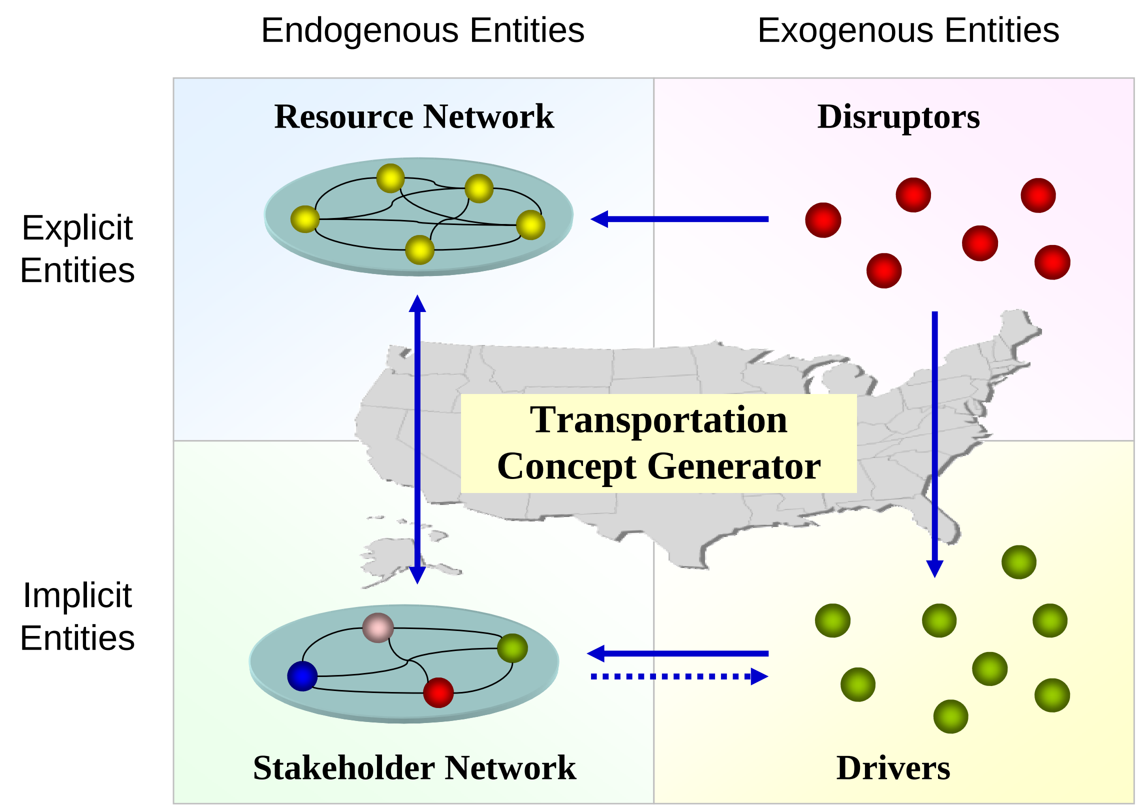


Mapping to Transportation

Level	Resources	Operations	Economics	Policy
α $(\vartheta\ 10^6)$	Vehicles & Infrastructure (e.g. aircraft, truck, runway)	Operating a Resource (Aircraft, truck, etc.)	Economics of building/operating/buying/selling /leasing a single resource	Policies relating to single resource use (e.g. type certification, flight procedures, etc.)
β $(\vartheta\ 10^4)$	Collection of resources for a common function (an airport, etc)	Operating resource networks for common function (e.g. airline)	Economics of operating/buying/selling /leasing resource networks	Policies relating to multiple vehicle use (e.g. airport traffic mangt, noise policies, etc.)
γ $(\vartheta\ 10^2)$	Resources in a Transport Sector (e.g. air transportation)	Operating collection of resource networks (e.g. ; commercial air Ops)	Economics of a Business sector (e.g. Airline Industry)	Policies relating to sectors using multiple vehicles. (safety, accessibility, etc.)
δ $(\vartheta\ 10^1)$	Multiple, interwoven sectors (resources for a national transportation system)	Operations of Multiple Business Sectors (i.e. Operators of total national transportation system)	Economics of total national transportation system (All Transportation Companies)	Policies relating national transportation policy
ε $(\vartheta\ 10^0)$	Global transportation system	Global Operations in the world transportation system	Global Economics of the world transportation system	Policies relating to the global transportation system

Transportation Abstraction

Our Model and Guide for the Study



Disruptors:

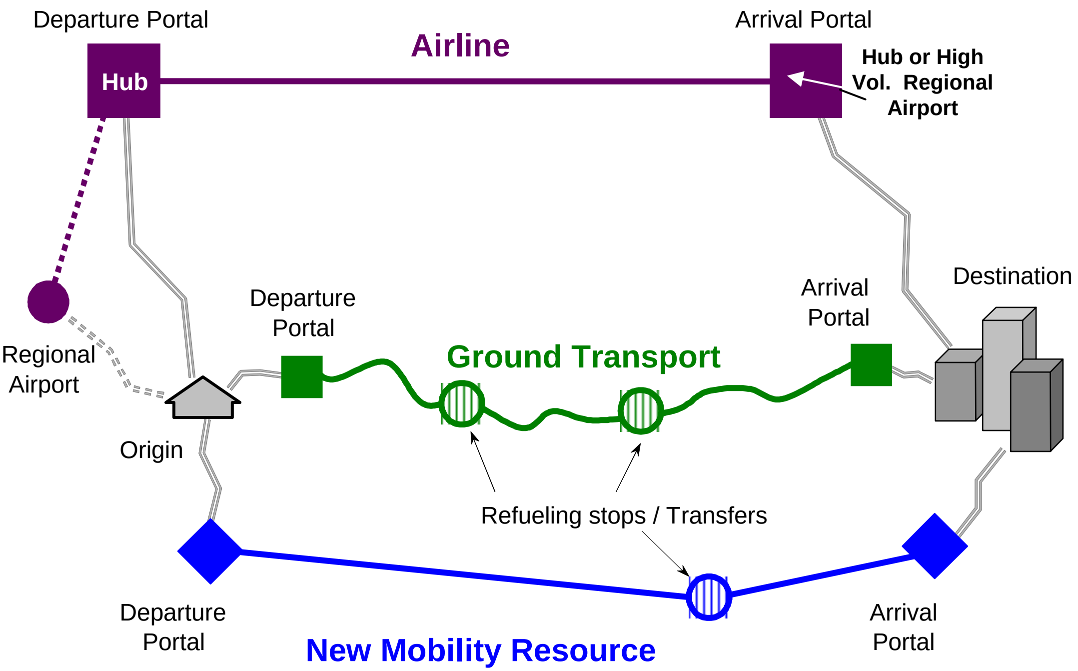
- Causing delay and/or cancellation of transportation activities
  - Natural disruptors: weather related events that affect operational condition of resources
  - Artificial disruptors: accident, terrorism, pollution

Drivers:

- Determine overall demand profile for transportation activities
  - Economic factors: GDP, household income, fuel price
  - Societal factors: demographic characteristics, urbanization trend
  - Psychological factors: culture, perception of safe/secure system

Resource Entities:

The Generic Trip



Enroute Entities

Rudiment	Items
Attributes	Types of portals and vehicles Path-length parameter Construction cost Operation cost & rule
Interfaces	Refueling/rest points Enroute delay effect (inter- and intra-city) Influence from weather effect Throughput of vehicles

Vehicle Entities

Category	Attributes
Operational Performance	Cruise speed Maximum range License requirement Payload capacity Near all-weather operations
Economic Characteristics	Acquisition cost Direct operation cost Insurance/maintenance cost Price/fee schedule
Infrastructure Compatibility	Types of portal Types of enroute space Dual mode capability

Portal Entities

Element	Description
Mode change	Required time to transfer from/to secondary mode
Wait-ahead	Required time for most scheduled services
Wait-in-line	Required time for processing ticketing, baggage claims and security check
Portal delay	Undesirable waiting time due to capacity limit, weather, etc.

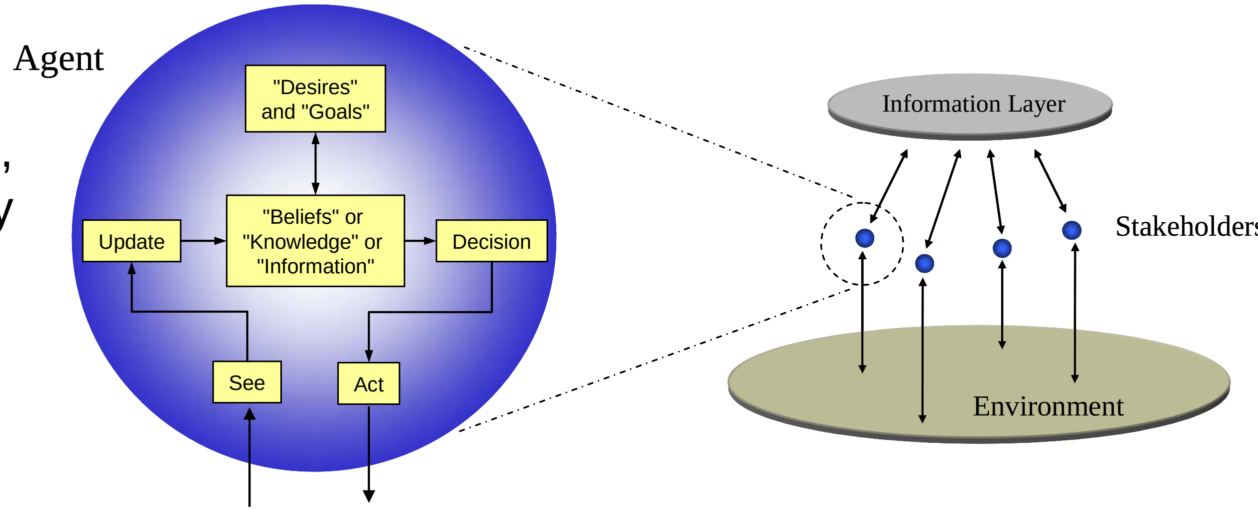
- Validate with (fixed) averages
- Simulate with (variable) values … sensitivities

Stakeholder Entities

Stakeholders		Descriptions	Objectives
Public	Consumers	Individual travelers or shippers (for commercial goods) that are the end user for the transportation system.	min: travel time, expense, max: comfort, safety
	Society	Represents the aggregated interests of citizens, from research agencies, to communities, to the national level.	min: noise, emission, max: quality of life
Industry	Service Providers	Owners of resources who sell transportation services to consumers.	max: profit, market share, consumers' satisfaction
	Manufacturers	Design, produce and sell transportation resources to service providers and/or consumers.	max: profit, market share, service providers' satisfaction
	Insurance Companies	Provide protections against mishap operation of transportation resources by collecting insurance fee.	max: profit, market share, customers' satisfaction
Government (Policymakers)	Regulatory Agencies	Impose rules on the system that restrict stakeholder activity and resource characteristics.	max: safety, security
	Infrastructure Providers	Plan and approve employment and enhancement of infrastructure resources.	max: capacity, min: delay
Indirect Stakeholders	Media	Report information, forecast and plan from/to the public.	Varied, but vague
	Research Agencies	Develop and provide transportation related technologies.	Provide firm foundation for transportation development

Agent-Based Modeling (ABM)

- Instead of prescribing the behavior dynamics, in ABM, individual agents (guided by behavioral rules) interact within the environment & system-wide effects are observed.



- Two major agent classes:
  - Software agents and simulation agents (“Sims”)
- Some simulation agent types:
  - Reactive: Simple reactions based on fixed rules
  - Intelligent: The β-level entities are the intelligent agents in our case
    - They generate the resource network (α-level entities) and a new NAS emerges at the γ-level, hopefully with the desired traits (scalable, desirable, accessibility)
    - May impart levels of autonomy, “learning”, into the α-level units to satisfy objectives
  - Mobile: Vehicles, Travelers

ABM Demo

- Go to Boids Demo

HTML
Document

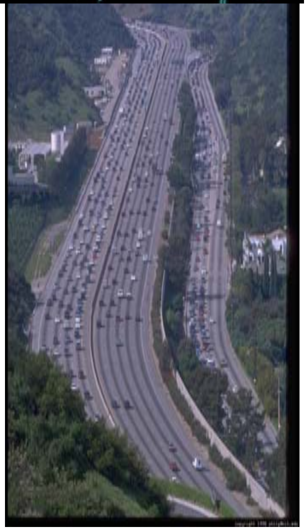
What's different about this modeling approach?

- *Emergence* -

- Emergence
  - "Persistent patterns" that emerge from small set of well-chosen building blocks constrained by simple rules (from Holland, 1998)
  - These patterns obey "macrolaws" that do not make direct reference to underlying generators.
- Predictive vs. Emergent
  - Linear vs. non-linear;
    - We (and our typical models) generally think in linear terms
  - Single layered vs. multi-level
  - Static vs. dynamic
- Value Added:
  - Uncover *landmine* or *jackpot* patterns over time, instead of point predictions for single systems (which are hardly ever right)

What is an “Emergent NAS”?

- Classic view: The NAS consists of … (Ref. Hansman, MIT)
  - Airports, Air Traffic Management, Weather, Personnel, Cost Recovery Mechanisms; True, but . . .
- NAS is most simply a series of networks: nodes and links
  - NAS networks are not designed, but generated
  - No single network represents the always correct answer
- Networks define connectivity (links) of packets (people) between points A and B (nodes)
  - Topologies “which nodes connected”
  - Accessibility “how often connected”
- The NAS networks are γ-level constructs; they arise based on rules in both the Resource and Stakeholder realms
  - The resource and stakeholder networks are intertwined
  - New innovations stimulate improvement in old technologies

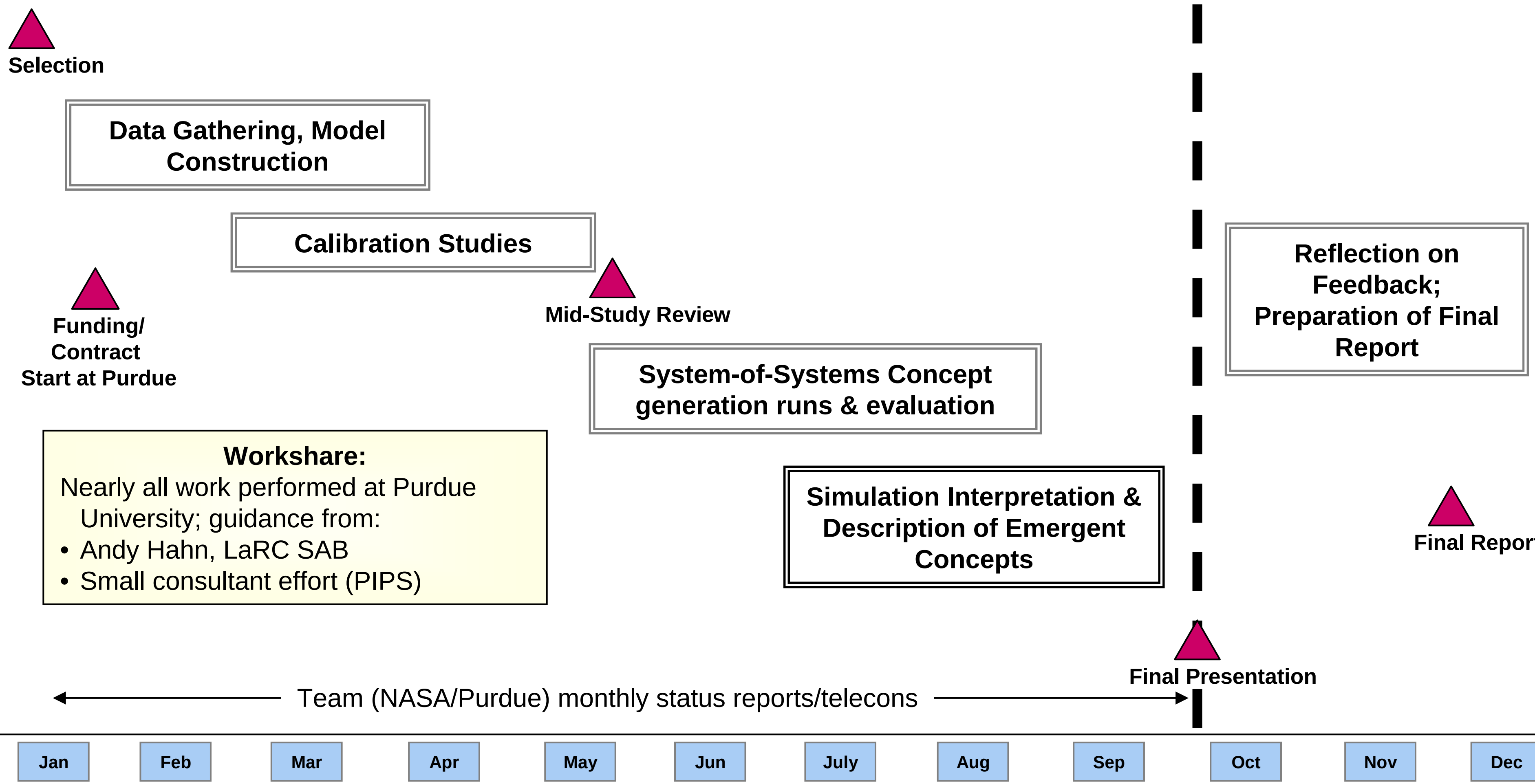


Summary Study Plan:

Implement Abstract Model and Simulate

1. Build: initial agents, generate environment, calibrate
   a. Simple network model with constraints
   b. Volpe mode split data (and existing tools we have)
   c. Rough comparison cases (e.g. LMI-3X)
2. Create: "clean sheet" ABM that evolves concepts for:
   a. Aircraft & Network concepts (portal operations, airspace ops)
   b. Business and regulatory concepts
   c. Factors in other modes
3. Simulate & Observe: Let the β-level agents organize themselves to respond to demands, disruptions, and drivers & thus:
   a. Select the α-level entity traits that they desire to meet this objective
   b. Generate the "new, emergent NAS", at the γ-level
4. Anticipated results: Answers to . . .
   a. What are the persistent patterns that emerge in the "new NAS" concepts?
   b. What are the simple agent rules that enable them?
   c. Where are the highest sensitivities & most significant barriers?

Study Plan/Schedule



Synopsis

- Key outcome: High-level simulation of “new NAS” Sys-of-Sys
- Desired objectives for “new NAS” concept(s)
  - Increased throughput and accessibility (e.g. “3X” increase)
  - Increased robustness (insensitivity to disruption: weather, resource, terrorism, traffic jams)
  - Increased “Natural”-ness
    - Minimal constraints and rules to get "good" behavior, naturally expressed
    - And, make money!
- The resulting set of concepts could be used to broadly guide both technology investment and regulatory direction of this complex Sys-of-Sys