A model-based systems engineering approach to simulate strategic and tactical performance in TCPED ground systems

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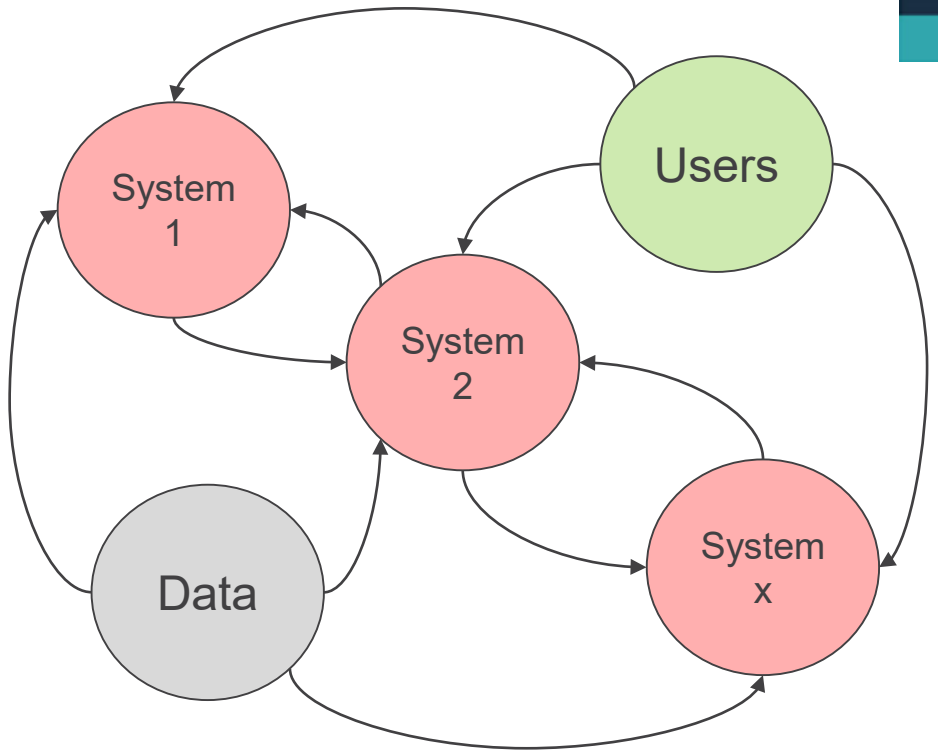
NATIONAL GEOSPATIAL NGA INTELLIGENCE AGENCY

Complexity of ground stations

[1]Creative Commons (CC0), Mysticsartdesign

Due to:

- Increase in data sizes[2]
- Resource sharing/partnerships
- Federated networks



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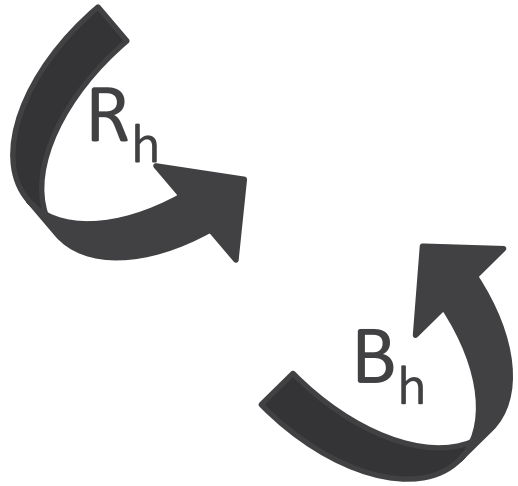
Causes of complexity

Dynamic complexity arises because systems are:

- Constantly changing
- Tightly coupled
- Governed by feedback
- Nonlinear
- History-dependent
- Self-organizing
- Adaptive
- Characterized by trade-offs
- Counterintuitive
- Policy resistant

(Sterman[3], 2002)



How is ground system behavior modeled over a 50+ year lifecycle?

Strategic versus tactical operations

f(Strategic)

- Mission planning
- Mission operations
- Data processing
- Dissemination
- R&D/Simulation
- Visualization

i(Tactical)

- Intelligence Prep of the Env. (IPOE)
- Operations centers
- Ground stations
- Comms/Storage
- Wargaming
- Common operating picture

r(Example)

- SPAWAR (MTC2)
- SPAWAR (MOC)/NGA (NOC)
- NAVO/NGA
- NAVO/NGA
- ONR (METOC)/NGA (A.I.)
- SPAWAR (CANES)/NGA (GEOINT Search & Retrieval, GEOINT Broker)

- *r*(Example) is one of many interagency collaborations.
- How many more collaborative events are currently ongoing?
- What are the explicit and implied relationships when interacting with dynamic and disperse ground systems?

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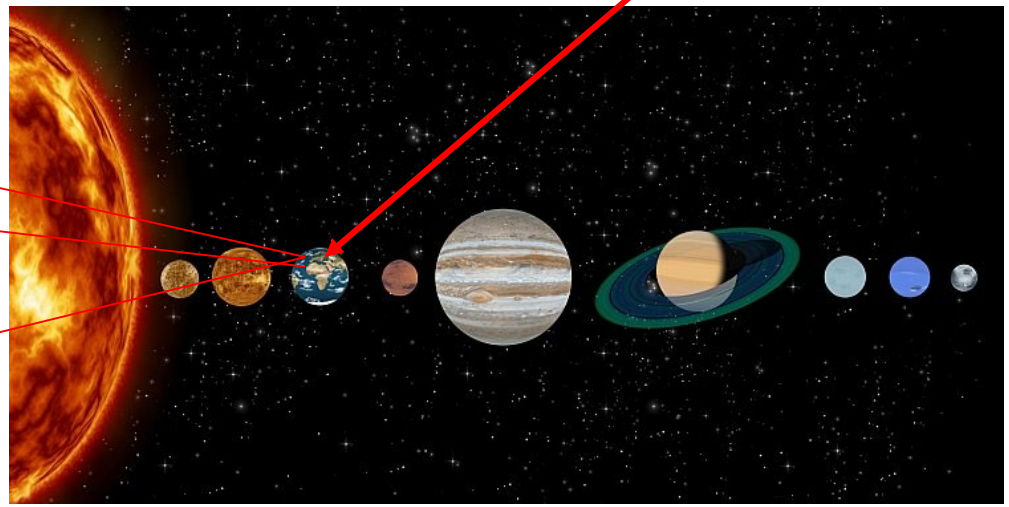
Current modeling techniques

- Collection
- Concurrent users
- Link-failure
- Prioritization
- Processing power
- Orbitology
- Throughput



[4]Public Domain Photography

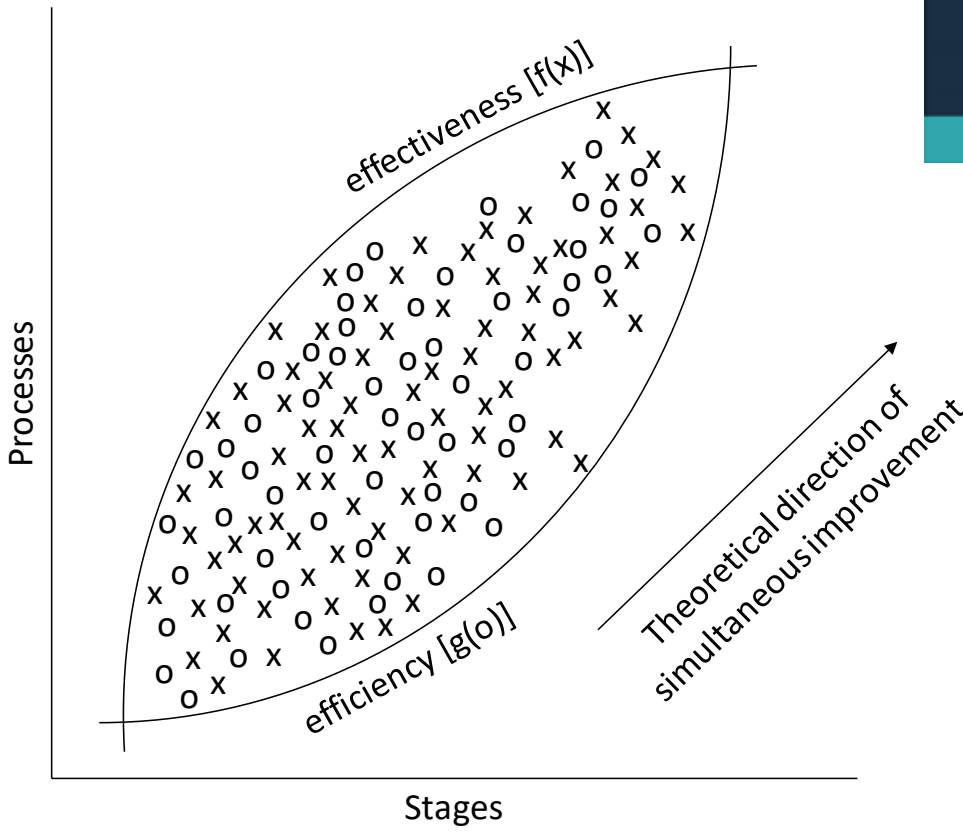
- Different models are currently used to monitor discrete relationships among ground components
- Great for tactical monitoring and root cause analysis of failures
- Certain models can be grouped to monitor similar discrete activities

How can multiple discrete models be combined to capture holistic dynamic properties?

Effectiveness versus efficiency

Stages	Randers (1980)	Richardson and Pugh (1981)	Roberts, et. al. (1983)	Wolstenholme (1990)	Sterman (2000)
	Conceptualization	Problem definition	Problem definition	Diagram construction and analysis	Problem articulation
		System conceptualization	System conceptualization		Dynamic hypothesis
	Formulation	Model formulation	Model representation	Simulation phase (stage 1)	Formulation
	Testing	Analysis of model behavior	Model behavior		Testing
		Model evaluation	Model evaluation		
	Implementation	Policy analysis	Policy analysis and model use	Simulation phase (stage 2)	Policy formulation and evaluation
		Model use			
		Processes			

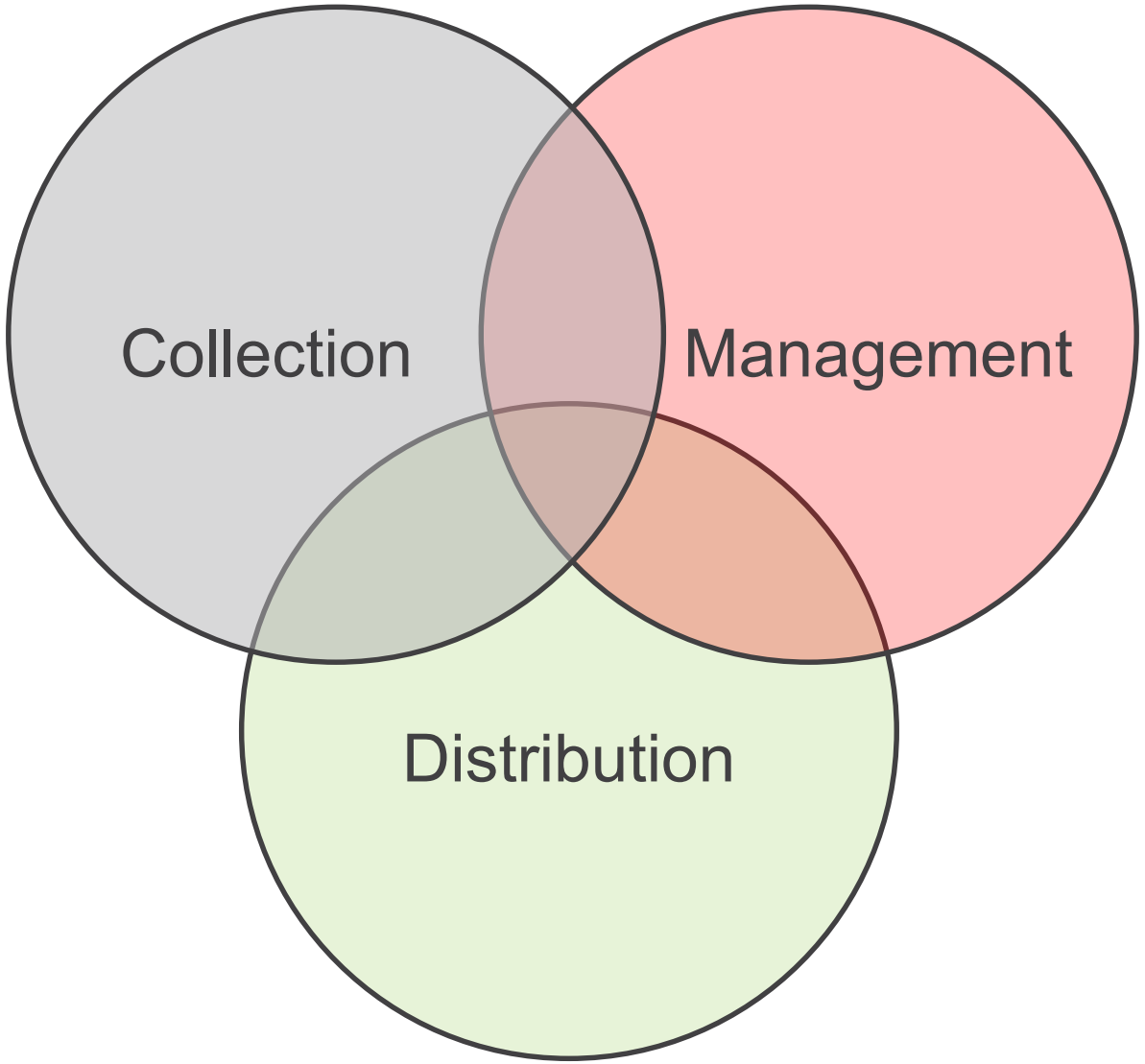
(Luna-Reyes[5], 2003)



- As the evolution and upgrades to ground systems occur:
  - How efficient are the upgrades being planned?
  - How effective are the upgrades?
  - How will improvement be measured (tested) prior to implementation (acquisition)?

Knowledge of change through simulations allow for improvement predictions prior to procurement.

System dynamics ground modeling



Purposeful aggregation of functions:

- Collection
- Management
- Distribution

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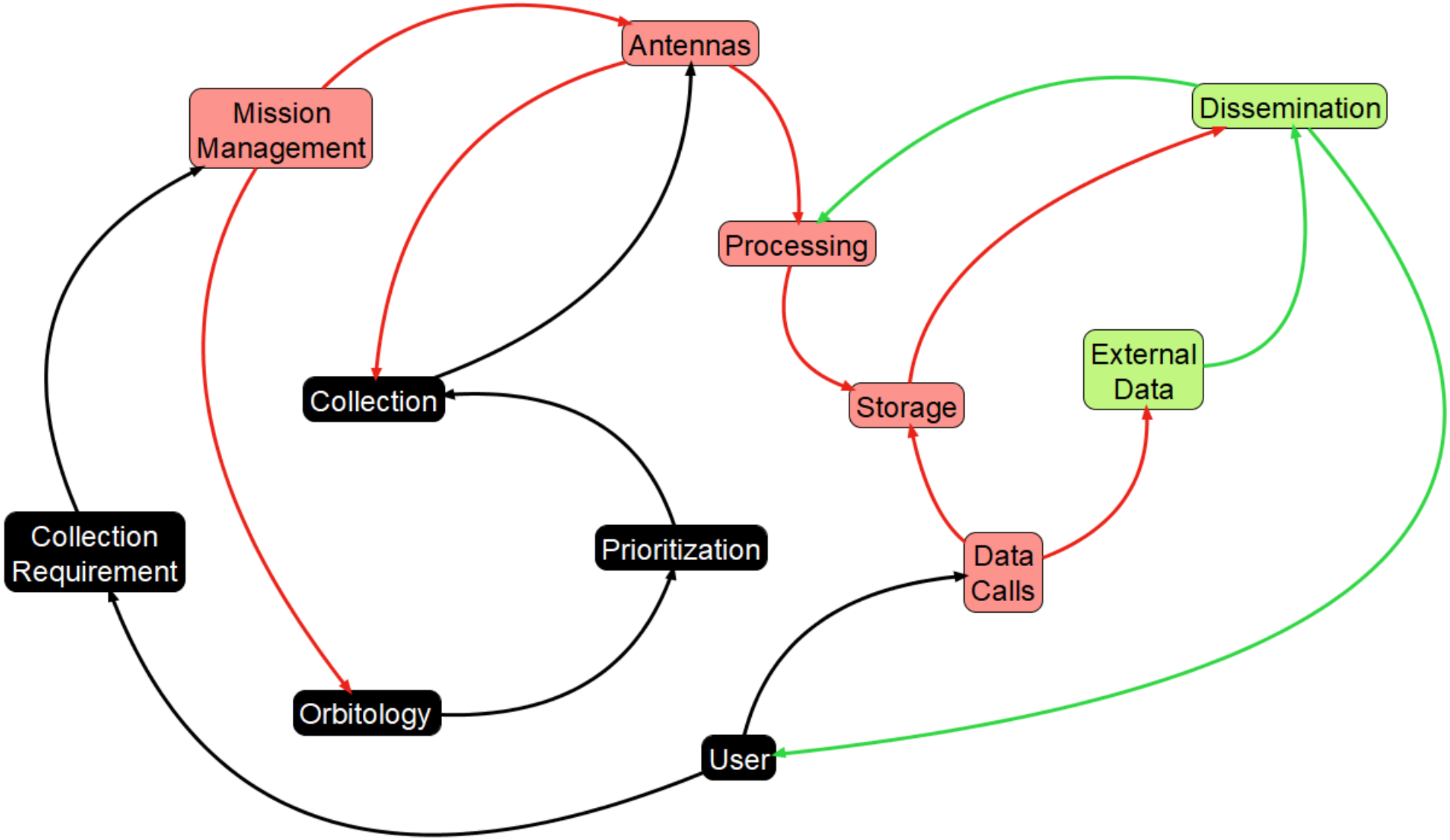
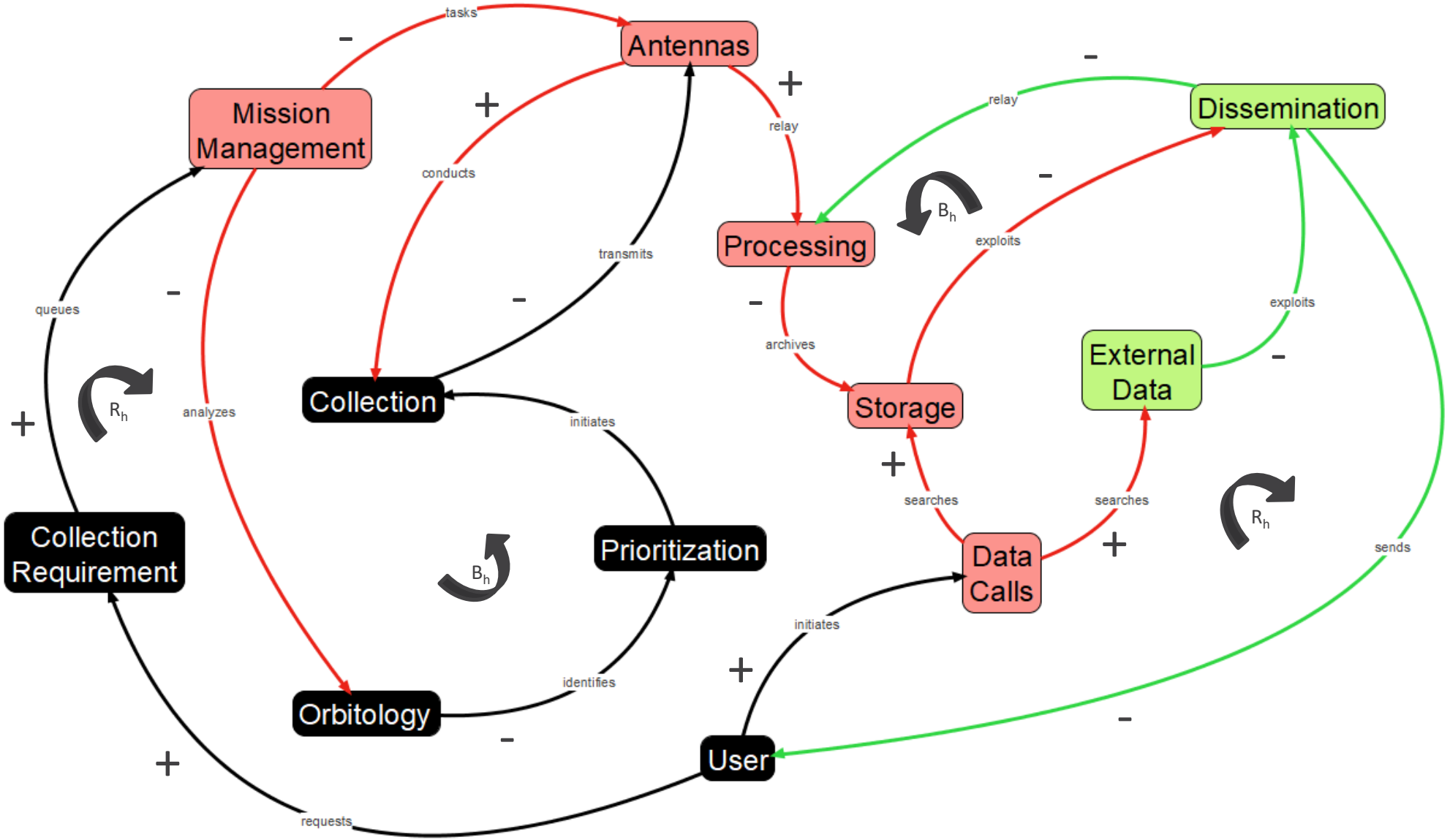
Conceptual data model



Logical data model



Understanding relationships for future performance impacts

Collection — Conceptual

H_0: Recurring/Balancing equation outputs — Logical

Discrete MBSE variables:
- # of sensors
- # of collection reqs.
- Prioritization schema

Management — Conceptual

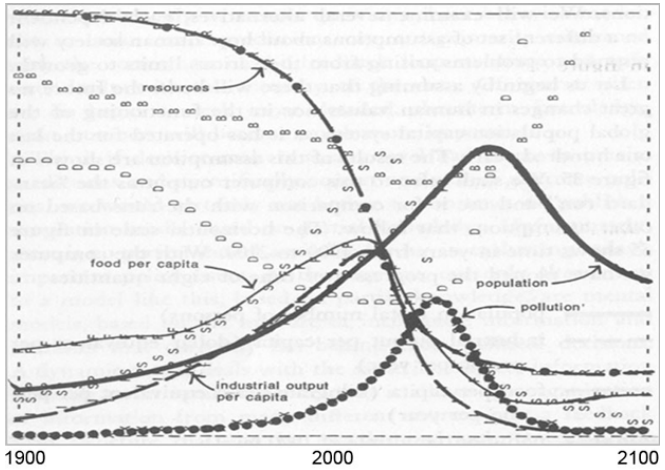
H_0: Recurring/Balancing equation outputs — Logical

Discrete MBSE variables:
- Processing power
- HW/SW types
- # of antennas
- # of concurrent users

Distribution — Conceptual

H_0: Recurring/Balancing equation outputs — Logical

Discrete MBSE variables:
- Mbps
- # of requests
- Comms capacity



*Notional output of recurring and balancing effects of a system[7]

Polarity of loop: SGN($\lambda x_1^0 / \lambda x_1^I$)

(Sterman[6], 2000, pg. 145)

Benefits of model-based performance simulations

- Provides measurement of system performance (HW/SW) based on planned operations & maintenance upgrades.
- Enables stressing of system components in a simulated environment
- Allows for virtual development and test prior to costly modifications

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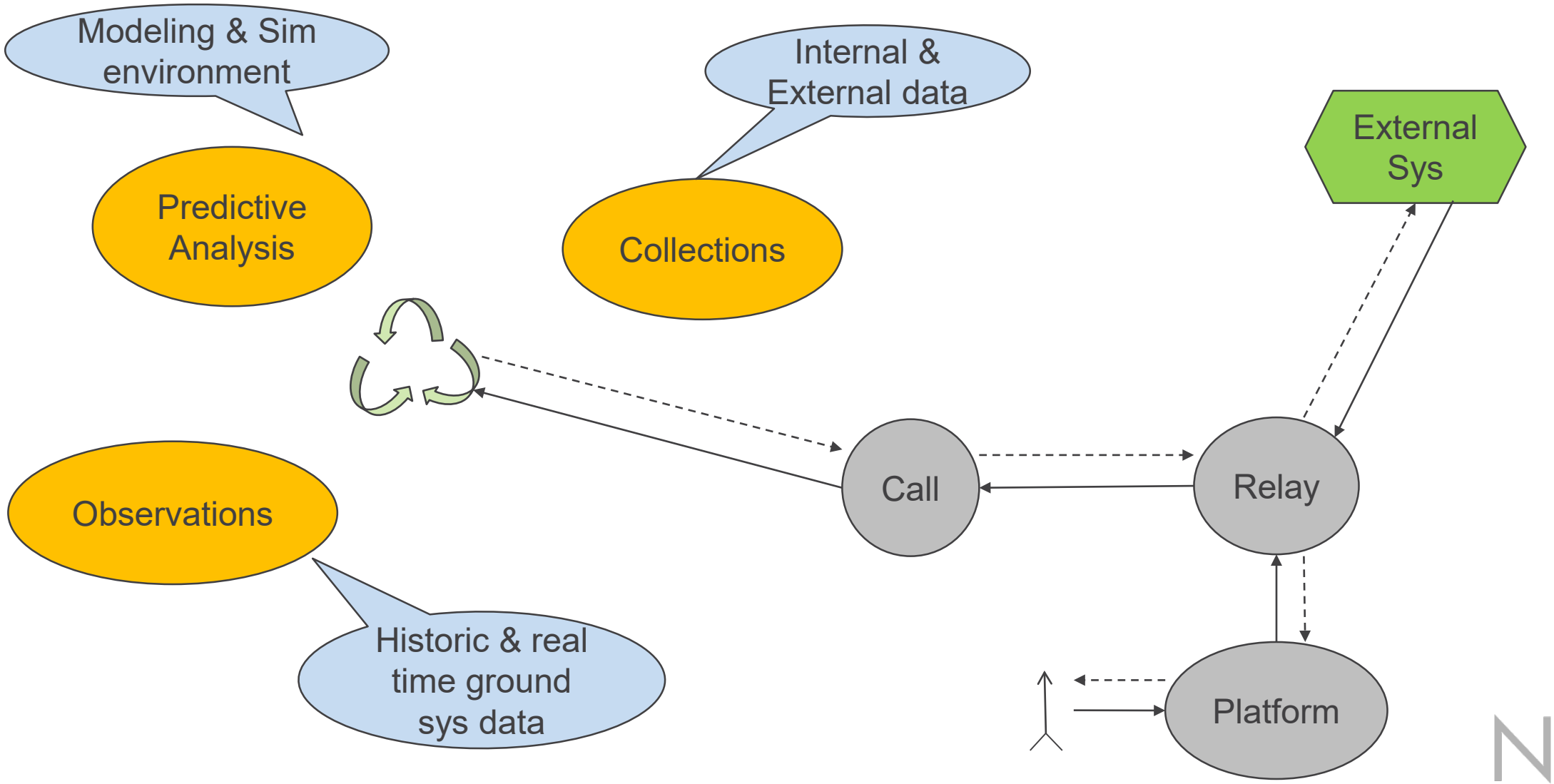
Future of federated ground architectures



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Next Steps

- Identify collaborative organizations interested in participating
- Collect discrete data across participants
- Normalize data
- Aggregate to Collection, Management and Distribution
- Develop a prototype modeling and simulation prototype environment

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Summary

- Ground systems are complex and dynamic.
- Recapitalization and new sources of data are inevitable.
- As non-linear approaches to ground system utilization evolve, how can one effectively evaluate changes?

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Presentation Sources

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7. Meadows, Donella H., et. al. The Limits of Growth, 1972. Volkswagen Foundation. www.thwink.org/sustain/glossary/SystemDynamics.html

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