A cloud-based modeling framework for complex advanced power systems

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Simulation, Modeling, & Decision Science

Increasing energy use

Increasing impact on the environment

Increasing resource scarcity

Energy and environmental challenges

Interactions between

Engineered, human, and natural systems

are confounded by complexity

Holistic solutions are needed

Today we cannot model the richness, fullness, or complexity of engineered, human, or natural systems.

New modeling approaches are needed

Many different models

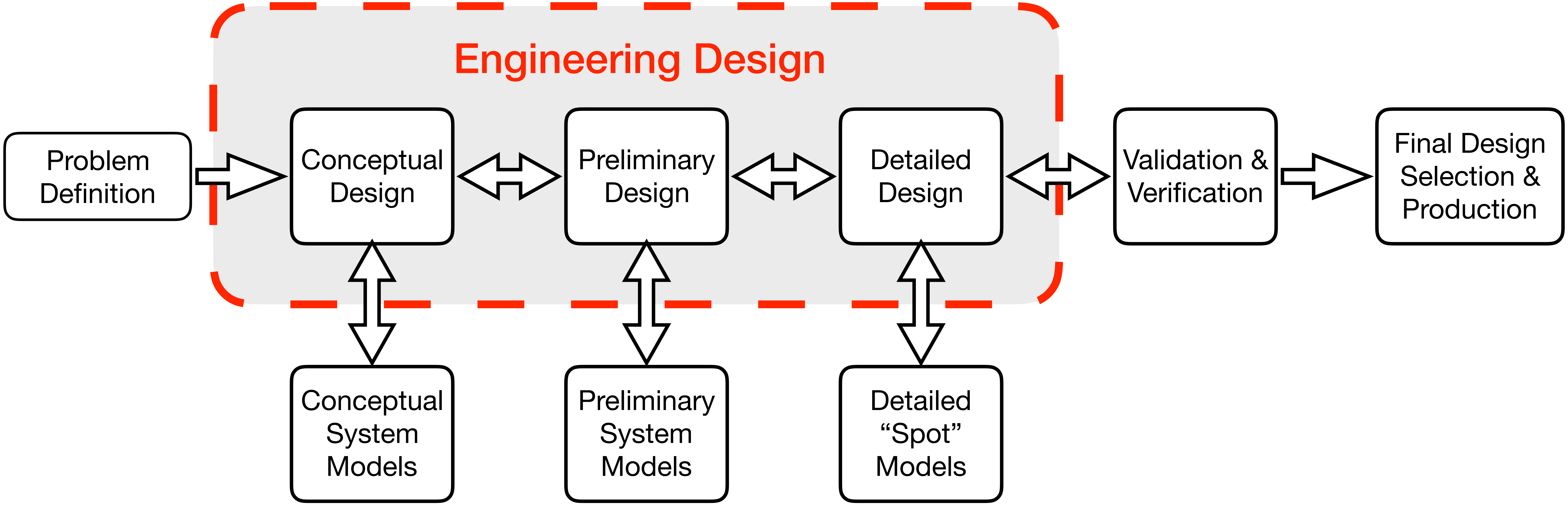
- No uniform, active storage space
- Not readily accessible, citable, or maintained
- Hard to locate and use existing code

Codes do not work together

- Systems models use codes specifically built for them
- Hard to use existing codes in a new systems model
- Clunky

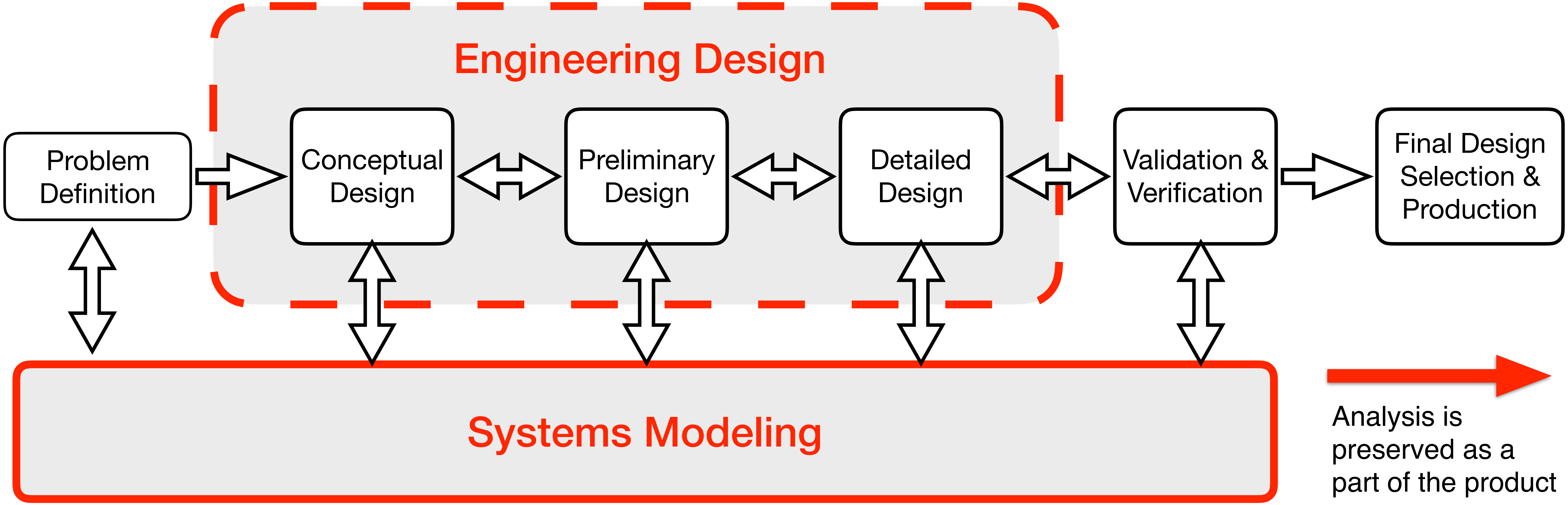
Systems modeling often lacks fidelity and granularity

- Algebraic expression, ODEs, reduced-order models
- Averaging and message passing



S Suram and KM Bryden, Advances in Engineering Software, 90:169-182 (2015)

Modeling and the Design Process Today



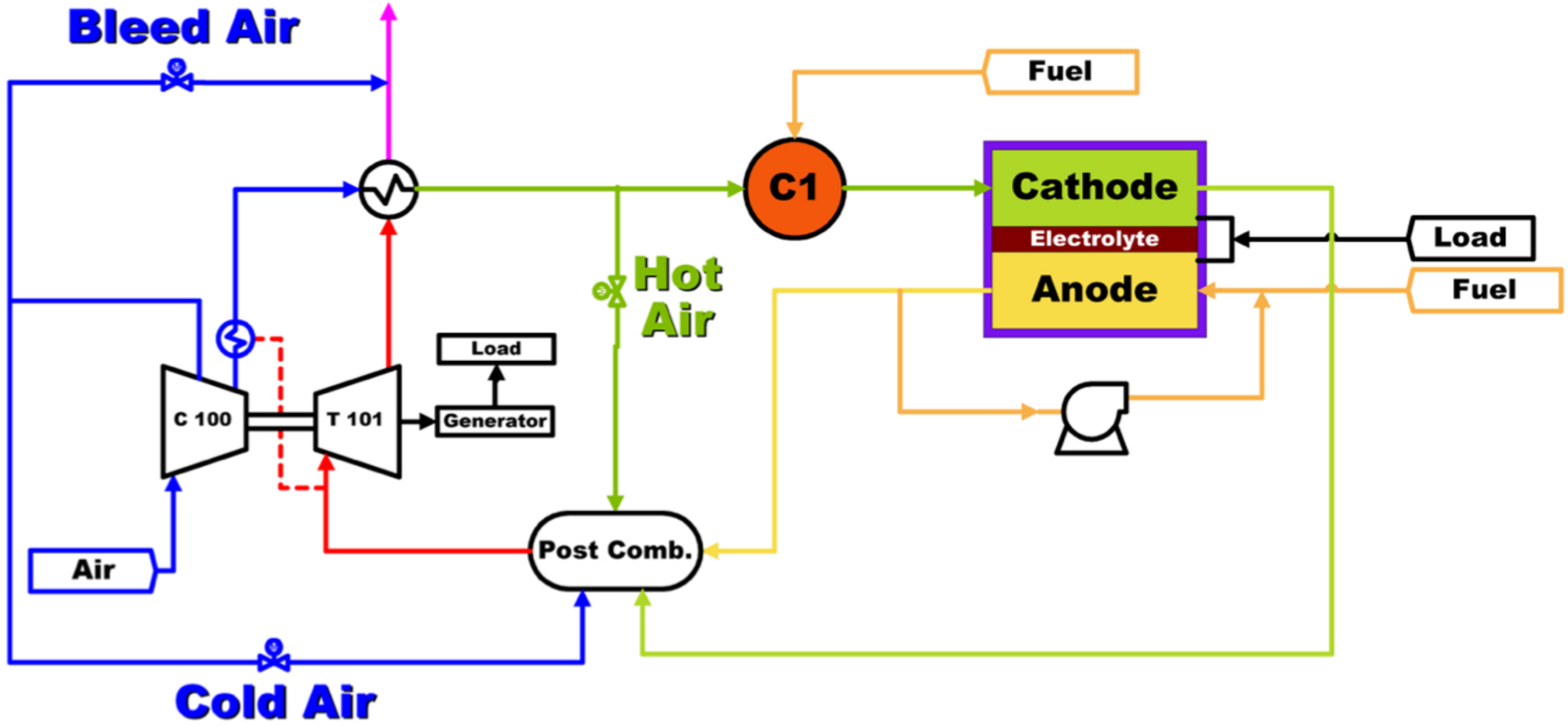
Proposed Design Process

Demonstrate the framework and tools needed to create detailed systems models based on reusable, accessible models that enable policy, engineering, and operational decisions for advanced fossil energy systems.

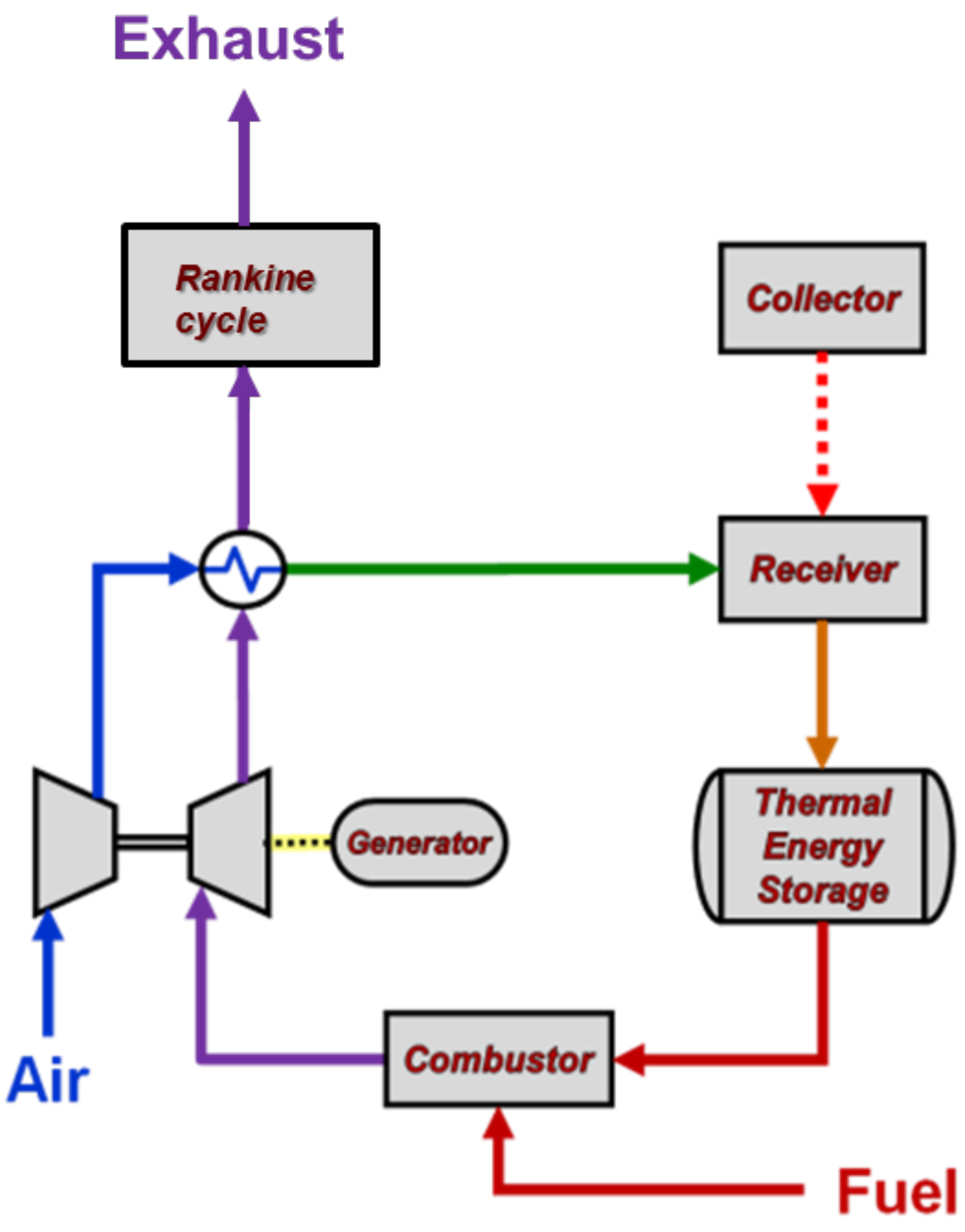
This requires the development of

- Web enabled information objects
- Federated model sets
- User interaction tools

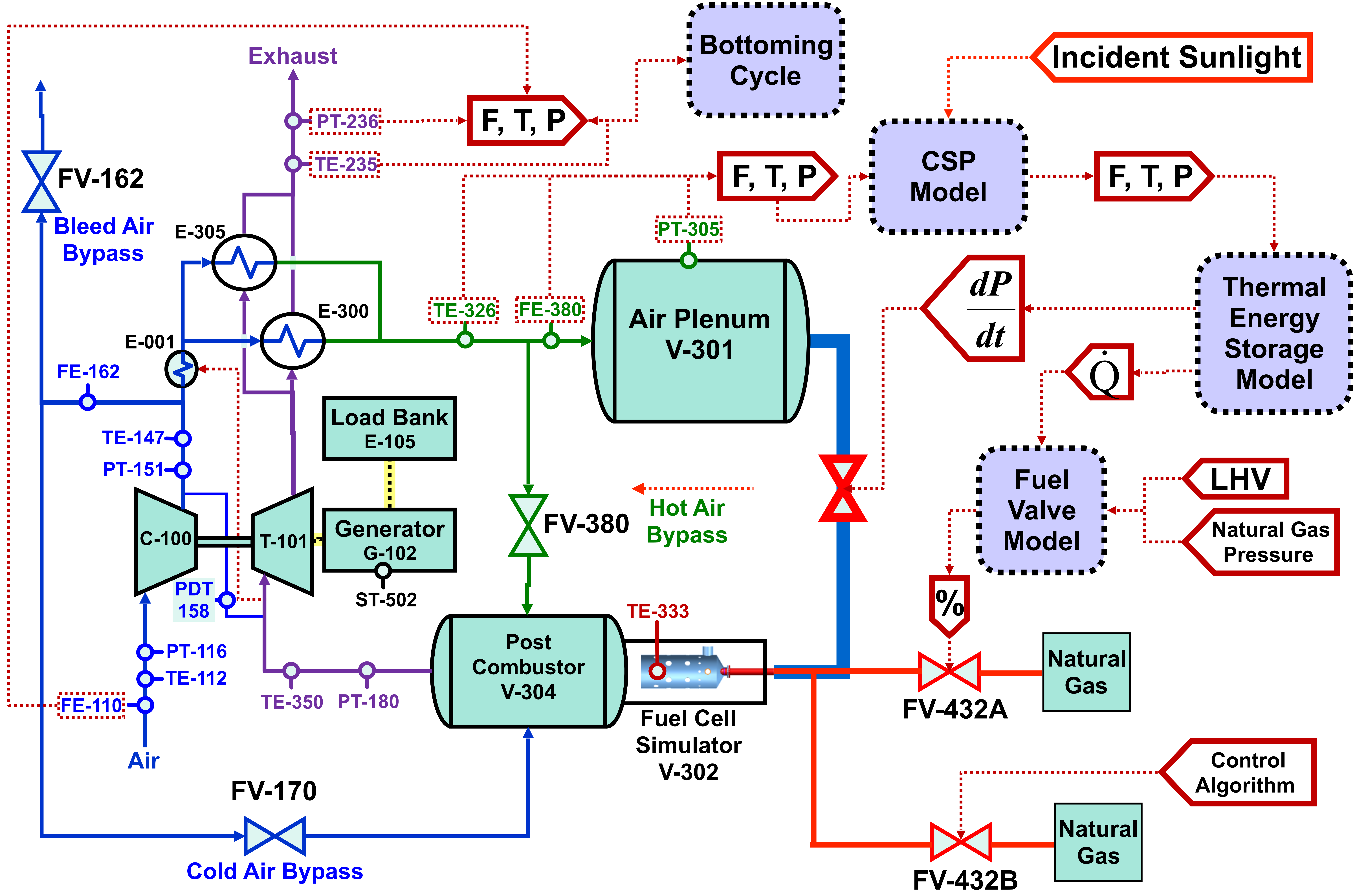
Project Objectives



- Current - a hybrid fuel cell and gas turbine system
- Goal - test the dynamic performance of any advanced power system that includes a gas turbine cycle



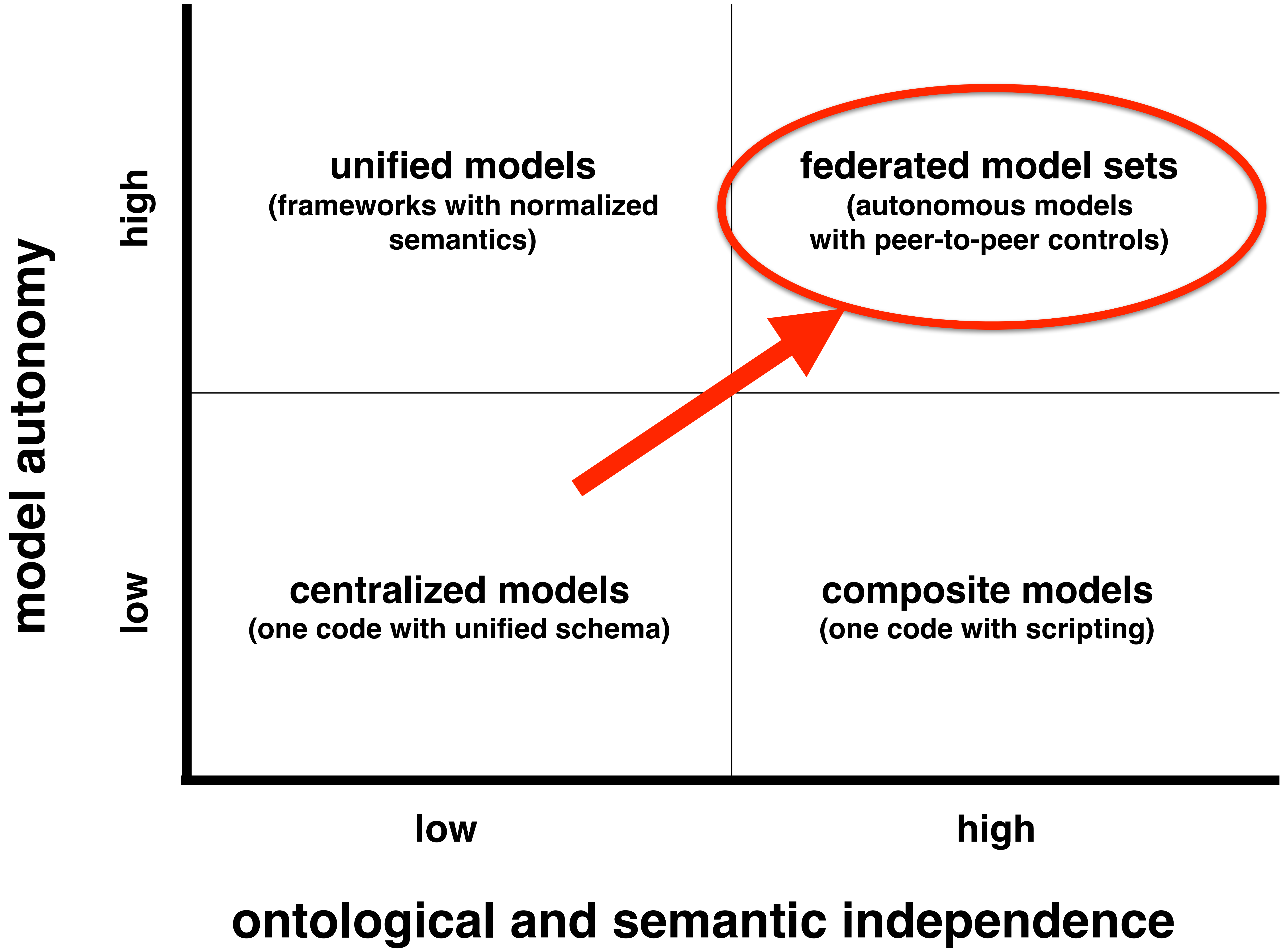
Hyper: CSP - Fossil Hybrid

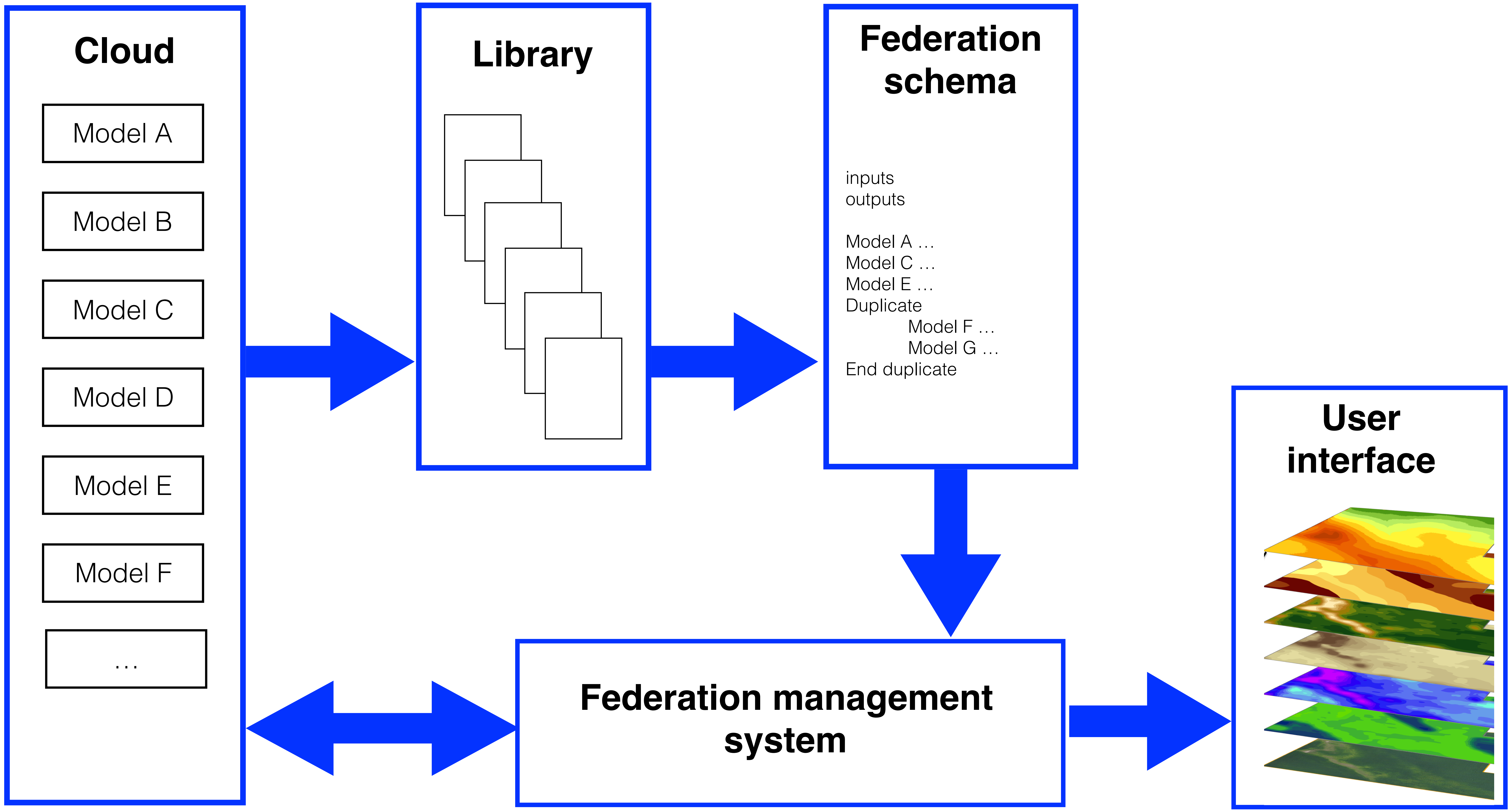


Exhaust
PT-236
TE-235
F, T, P
Bottoming Cycle
Incident Sunlight
FV-162
Bleed Air Bypass
E-305
E-300
E-001
FE-162
TE-326
FE-380
PT-305
F, T, P
CSP Model
F, T, P
Air Plenum V-301
dP
dt
Thermal Energy Storage Model
Q̇
TE-147
PT-151
Load Bank E-105
Generator G-102
C-100
T-101
FV-380
Hot Air Bypass
Fuel Valve Model
LHV
Natural Gas Pressure
PDT 158
ST-502
TE-333
%
Post Combustor V-304
PT-116
TE-112
FE-110
TE-350
PT-180
Fuel Cell Simulator V-302
Natural Gas
FV-432A
Air
FV-170
Cold Air Bypass
Control Algorithm
Natural Gas
FV-432B

- Why can’t we integrate analysis into engineering decision making on-the-fly?
- Why isn’t engineering analysis like a game?
- Why do we continually make new models?

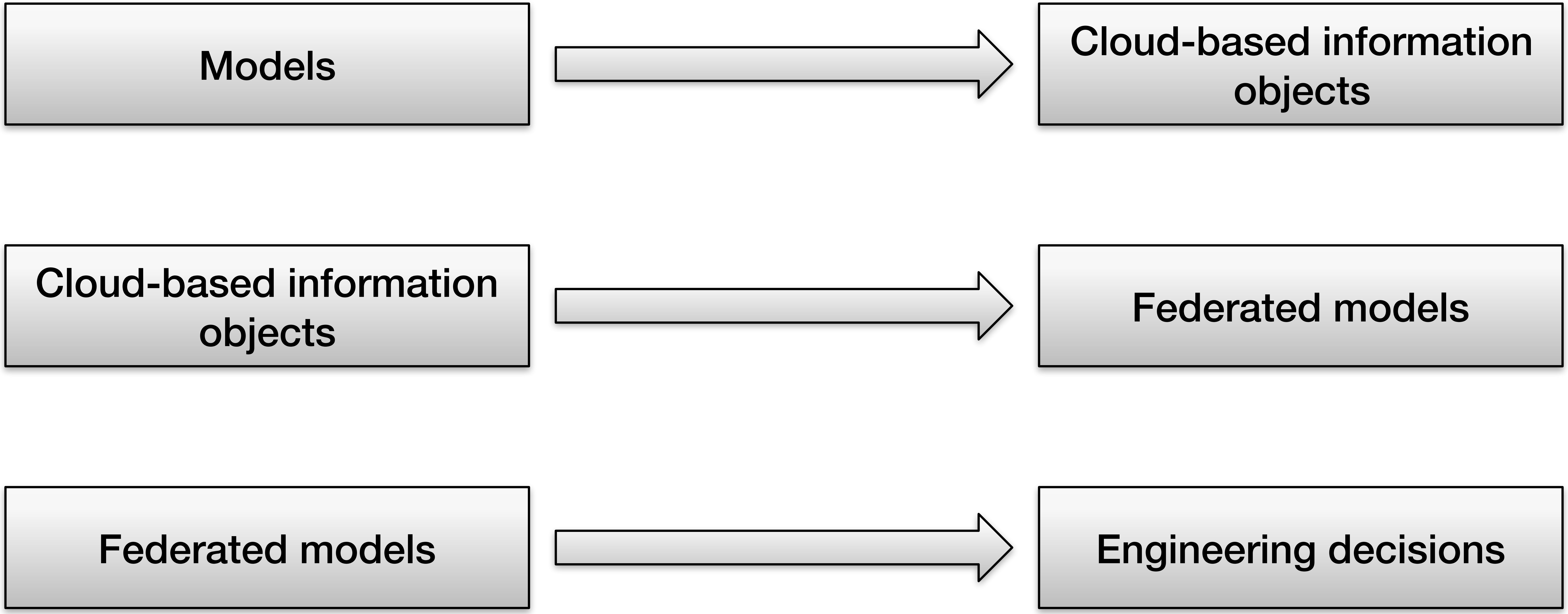
Three questions


unified models
(frameworks with normalized semantics)
federated model sets
(autonomous models with peer-to-peer controls)
centralized models
(one code with unified schema)
composite models
(one code with scripting)
model autonomy
high
low
low
high
ontological and semantic independence

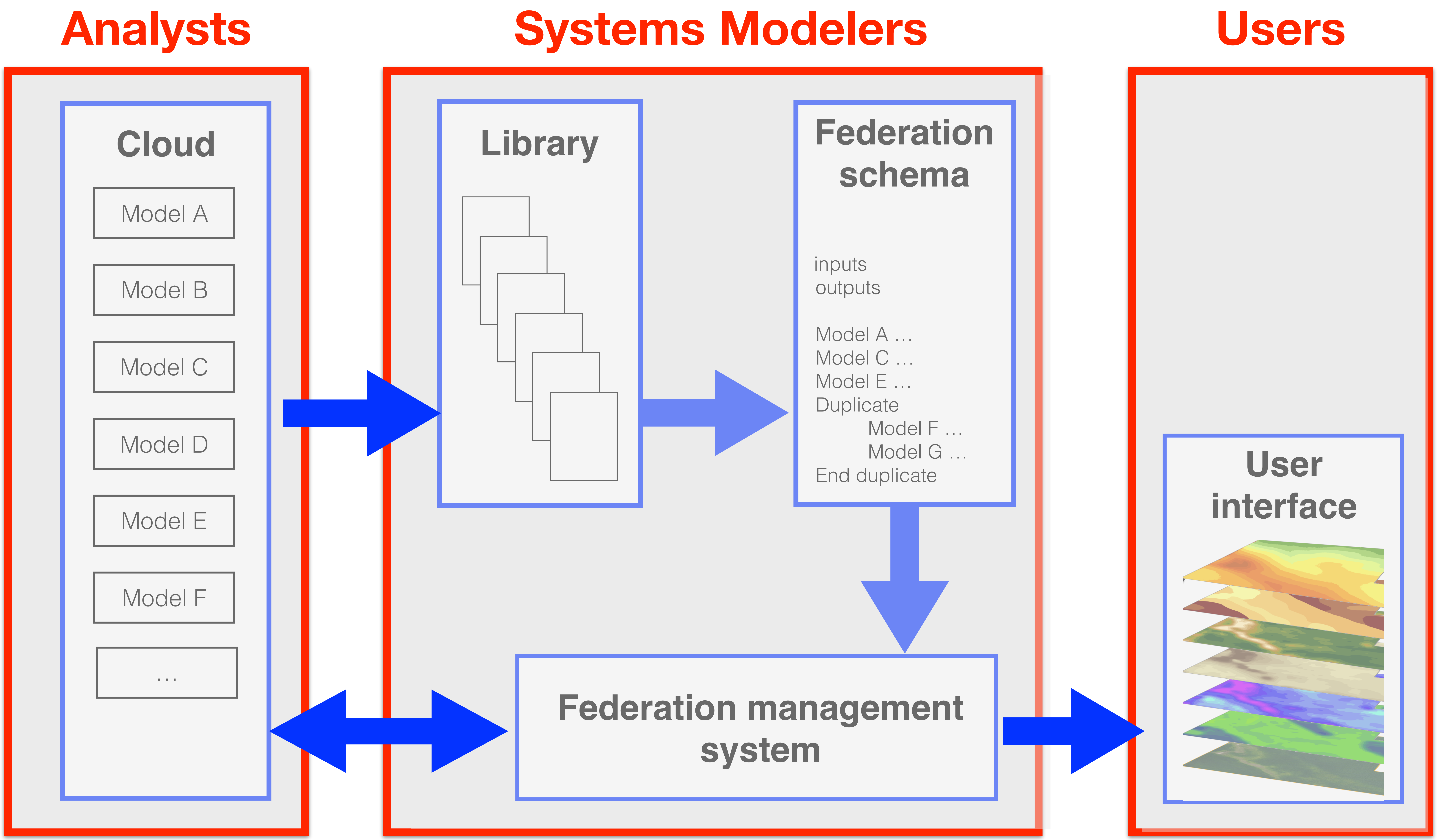


K. M. Bryden, Proceedings of the 7th International Congress on Environmental Modelling and Software (2014).

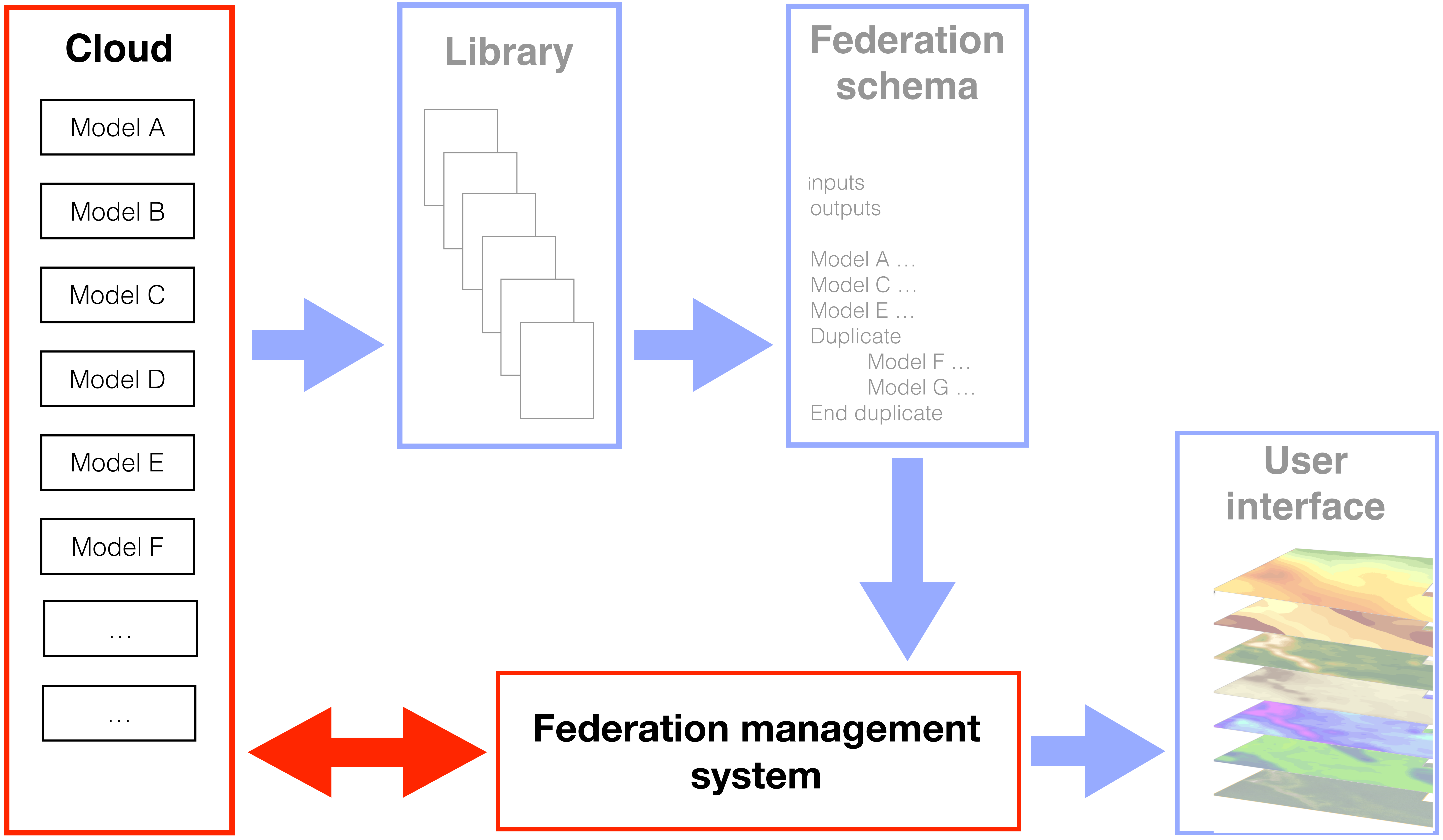
Approach



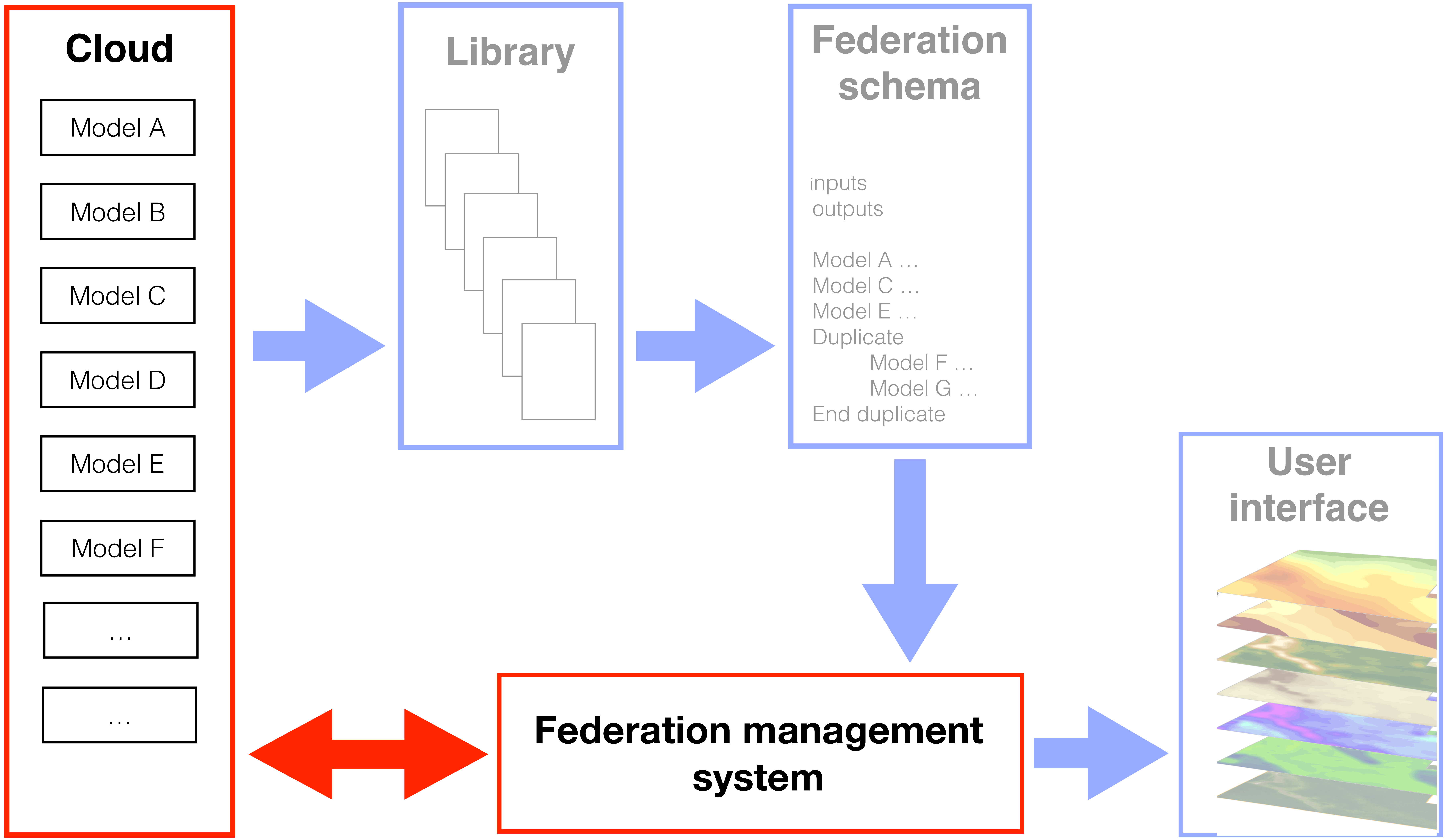
What’s needed


Analysts
Systems Modelers
Users
Cloud
Model A
Model B
Model C
Model D
Model E
Model F
…
Library
Federation schema
inputs
outputs
Model A …
Model C …
Model E …
Duplicate
Model F …
Model G …
End duplicate
Federation management system
User interface

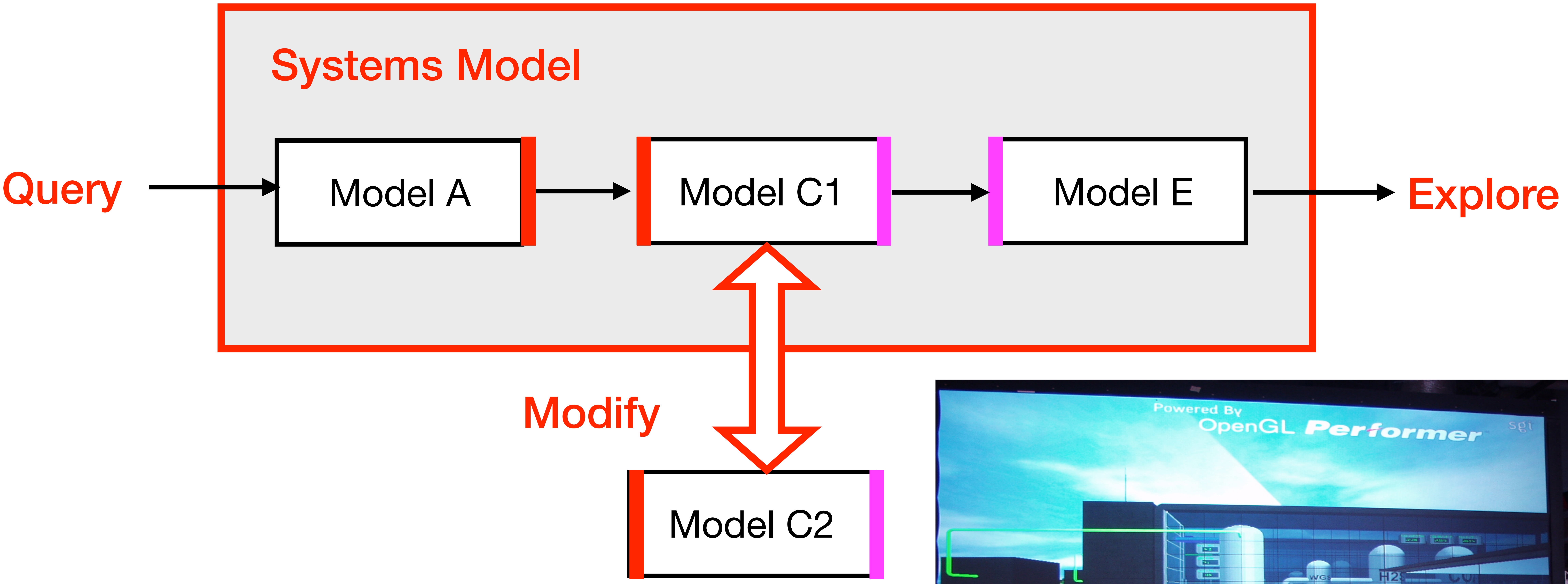
Work flow



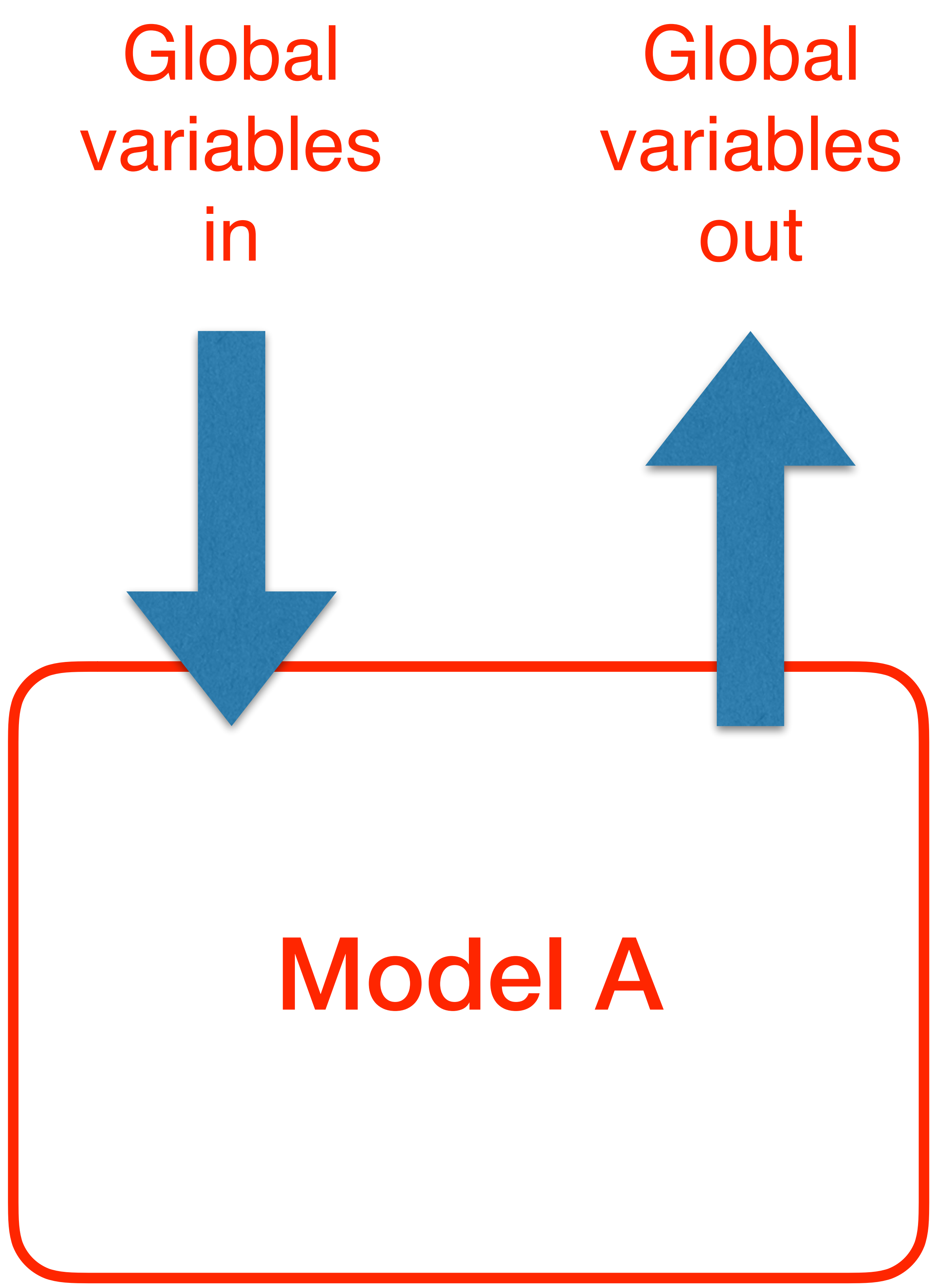
Components and information flow



Components and information flow



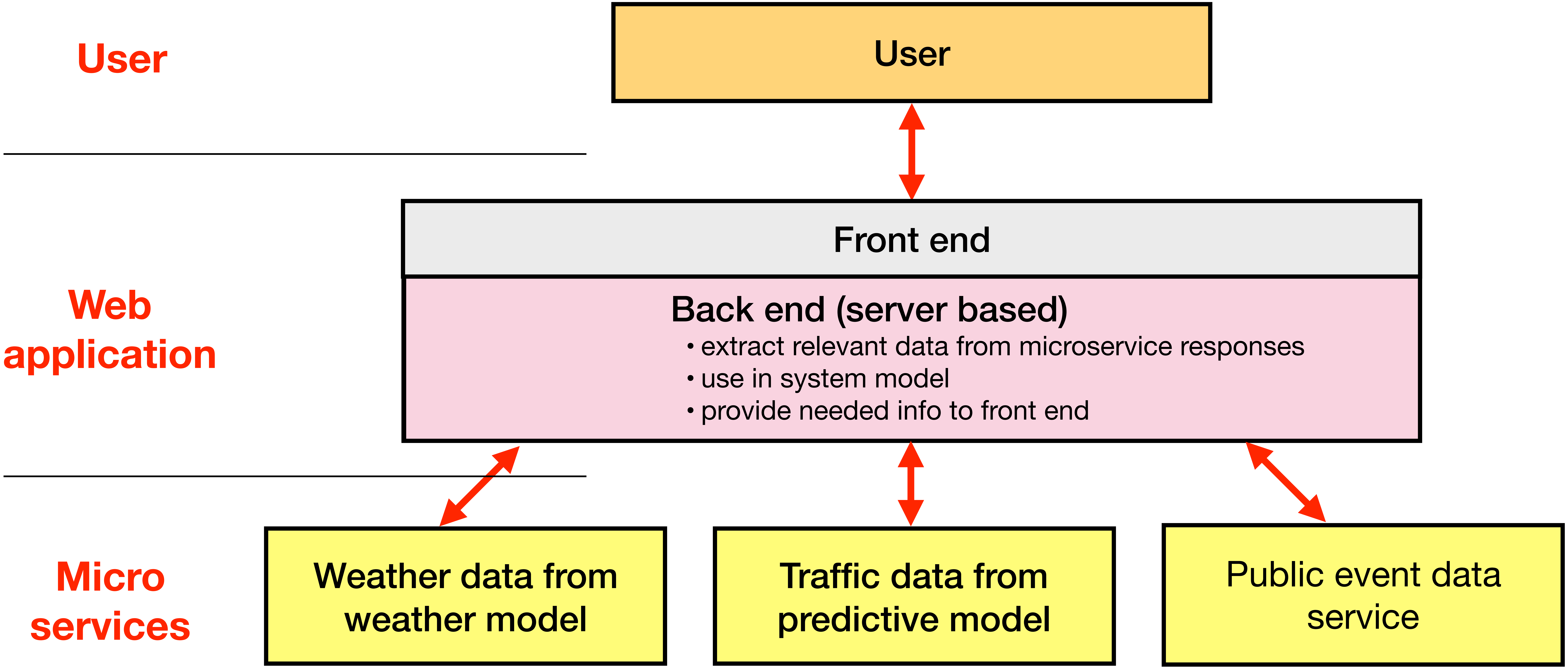
User experience



Each request is treated as an independent request

- communication is an independent set of a request and a response
- no session information is retained
- the code has no knowledge of the actions of other codes within the federation
- each member of the federation performs a specific task
- models are reusable for other analysis
- models can be strung together like beads on a complex weaving

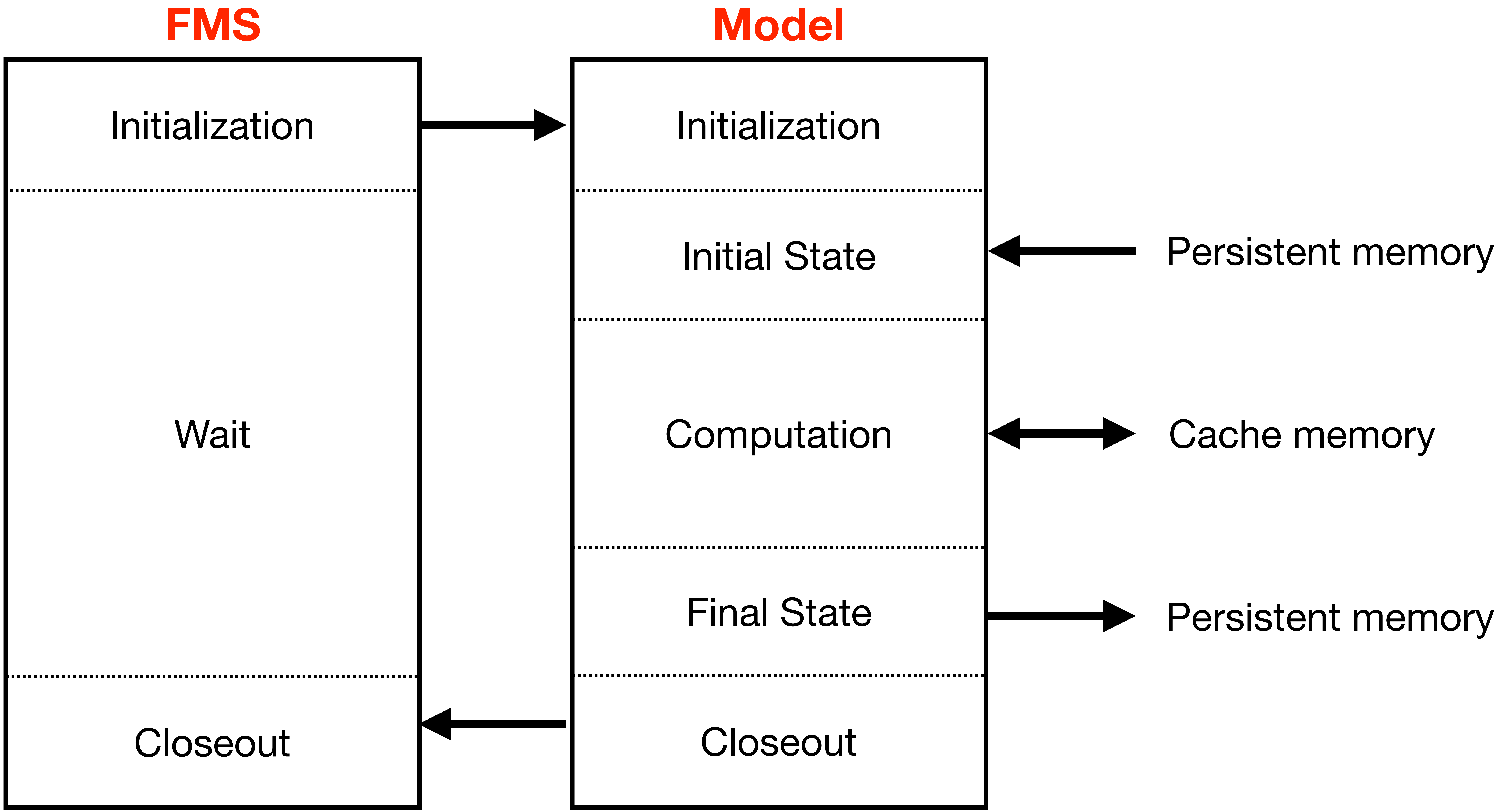
Stateless modeling



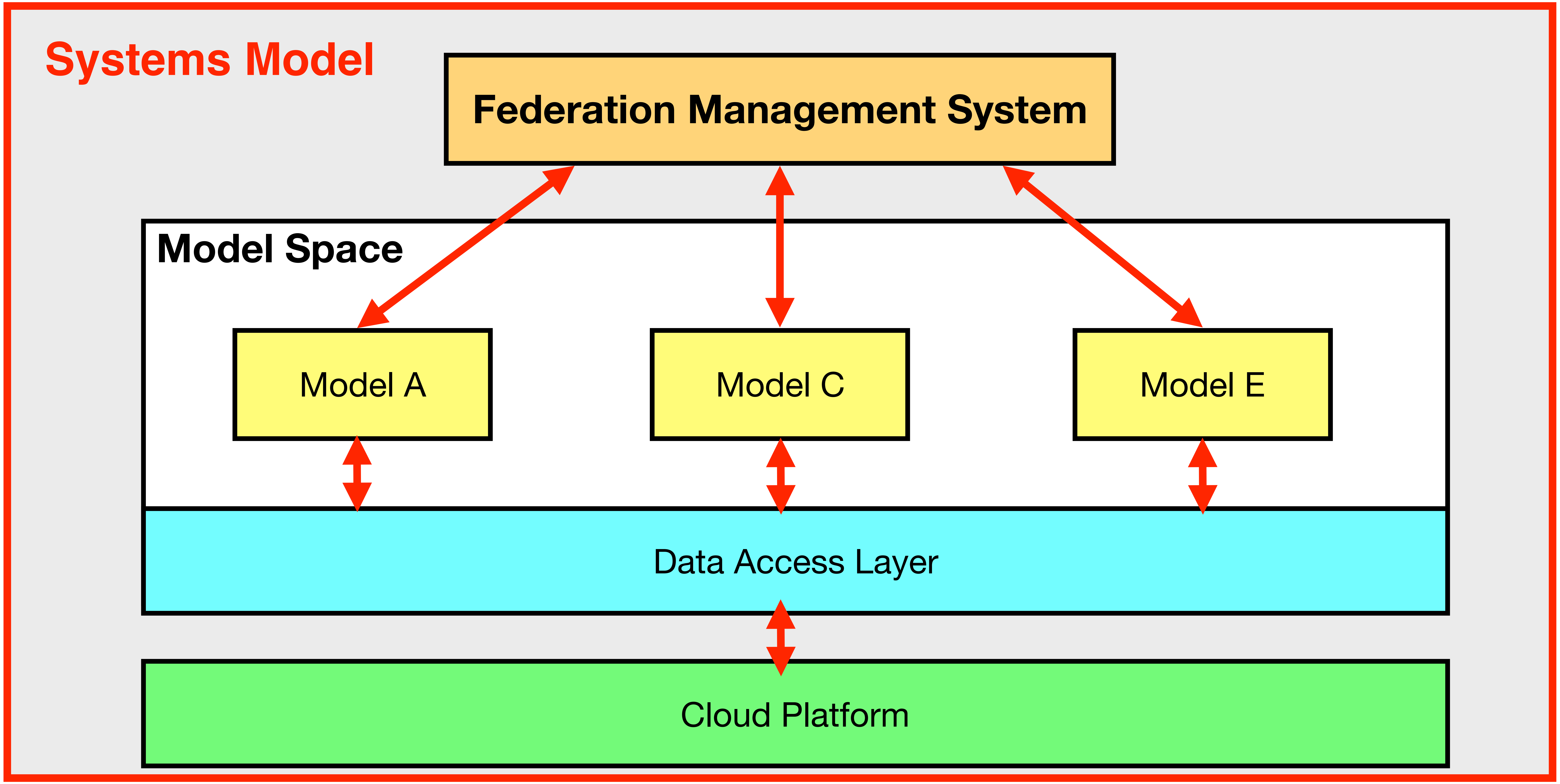
App implementation (microservices architecture)

- independently deployable
- easy assembly of various models and information sources
- models can be implemented using different programming languages, databases, hardware, and software environments
- direct replacement of a federation member can be performed without disruption to other members or the federation
- microservices perform (provide) one task only
- microservices are reusable

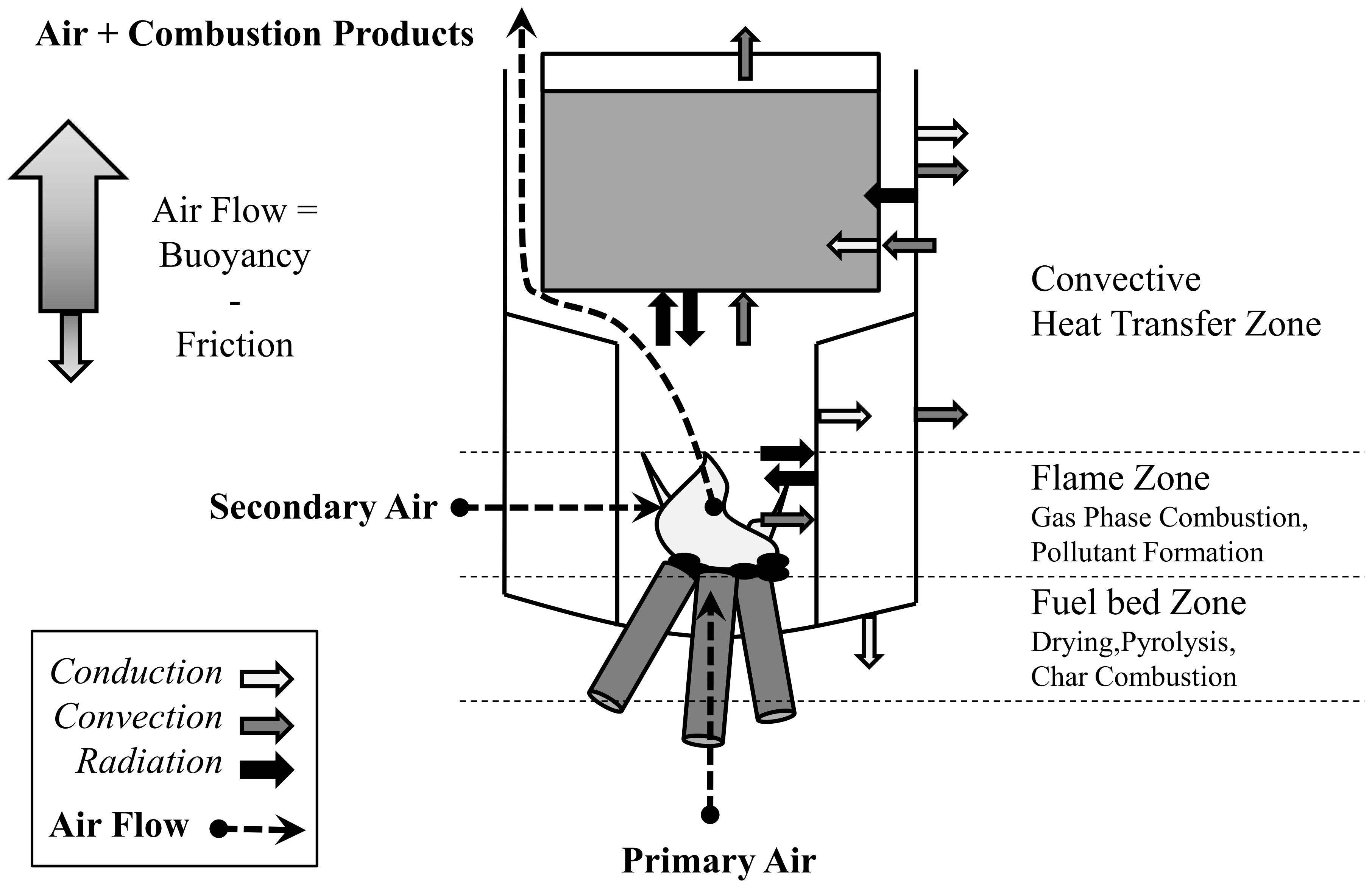
Properties of a microservices architecture

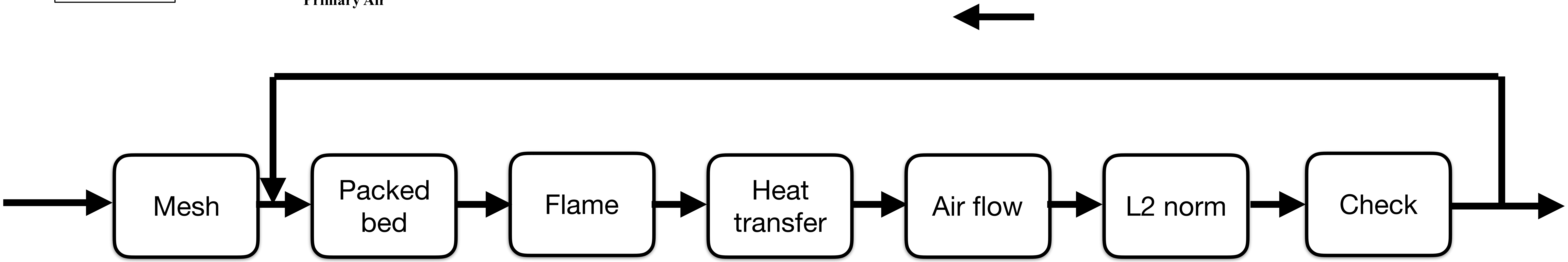


FMS - model interaction

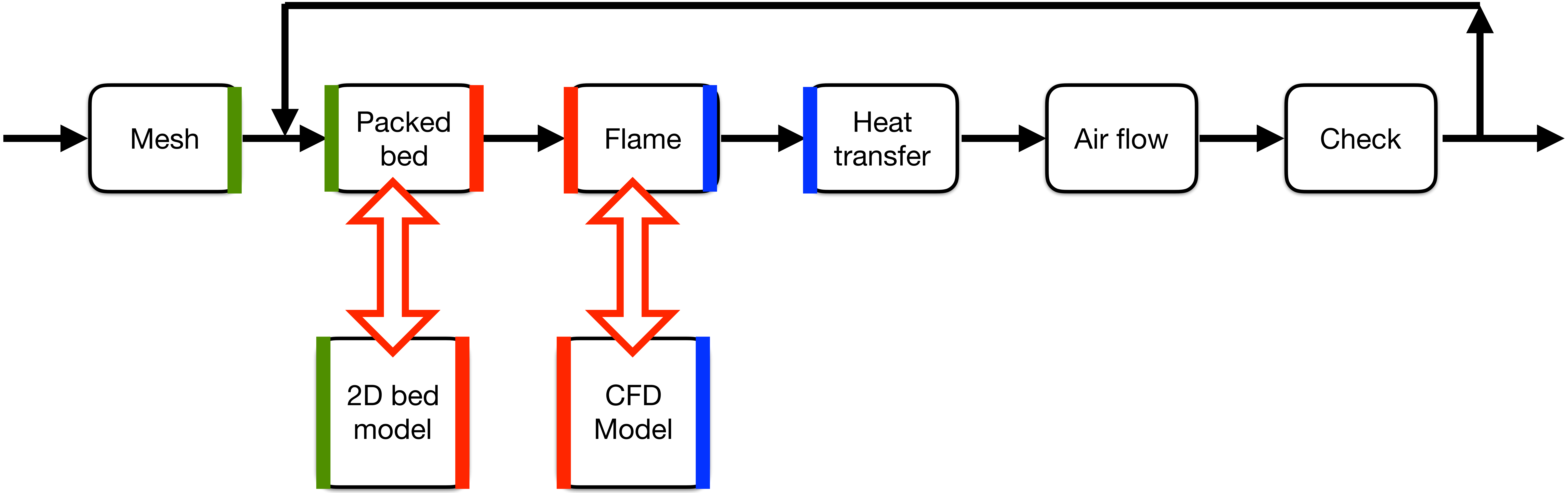


Model space architecture





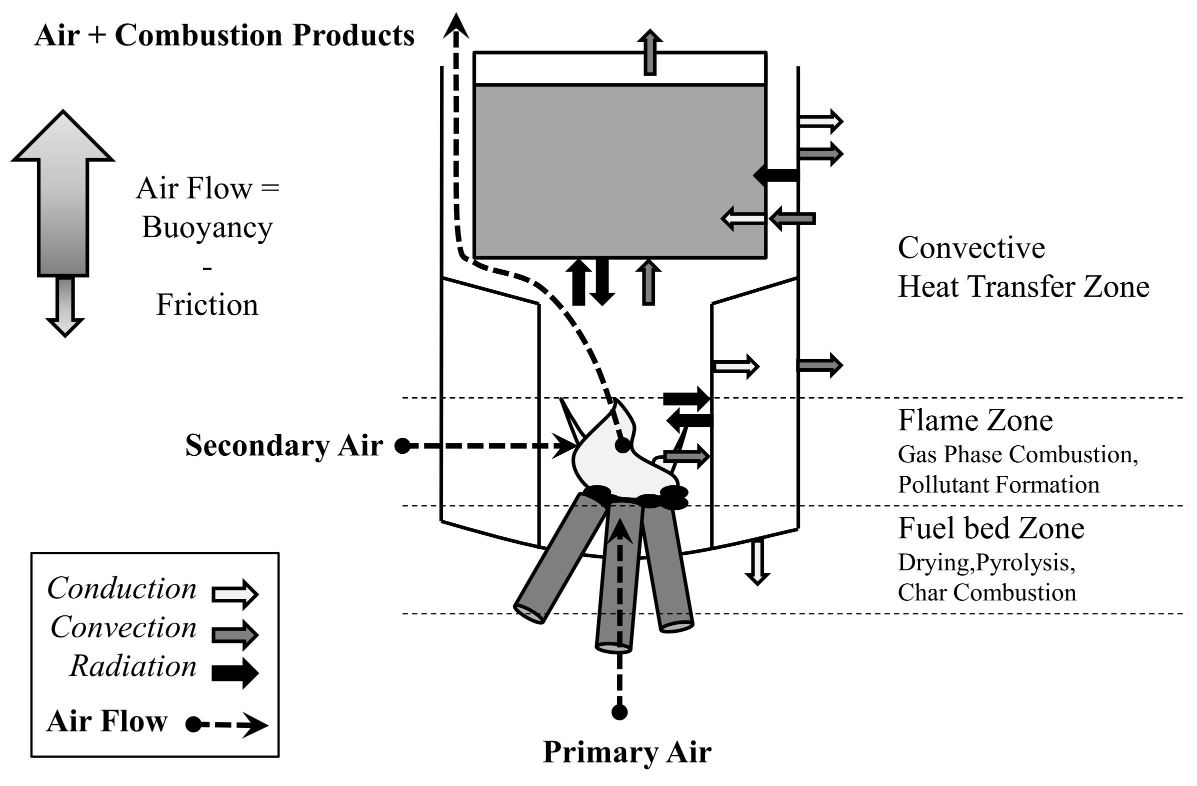
Small cookstove model

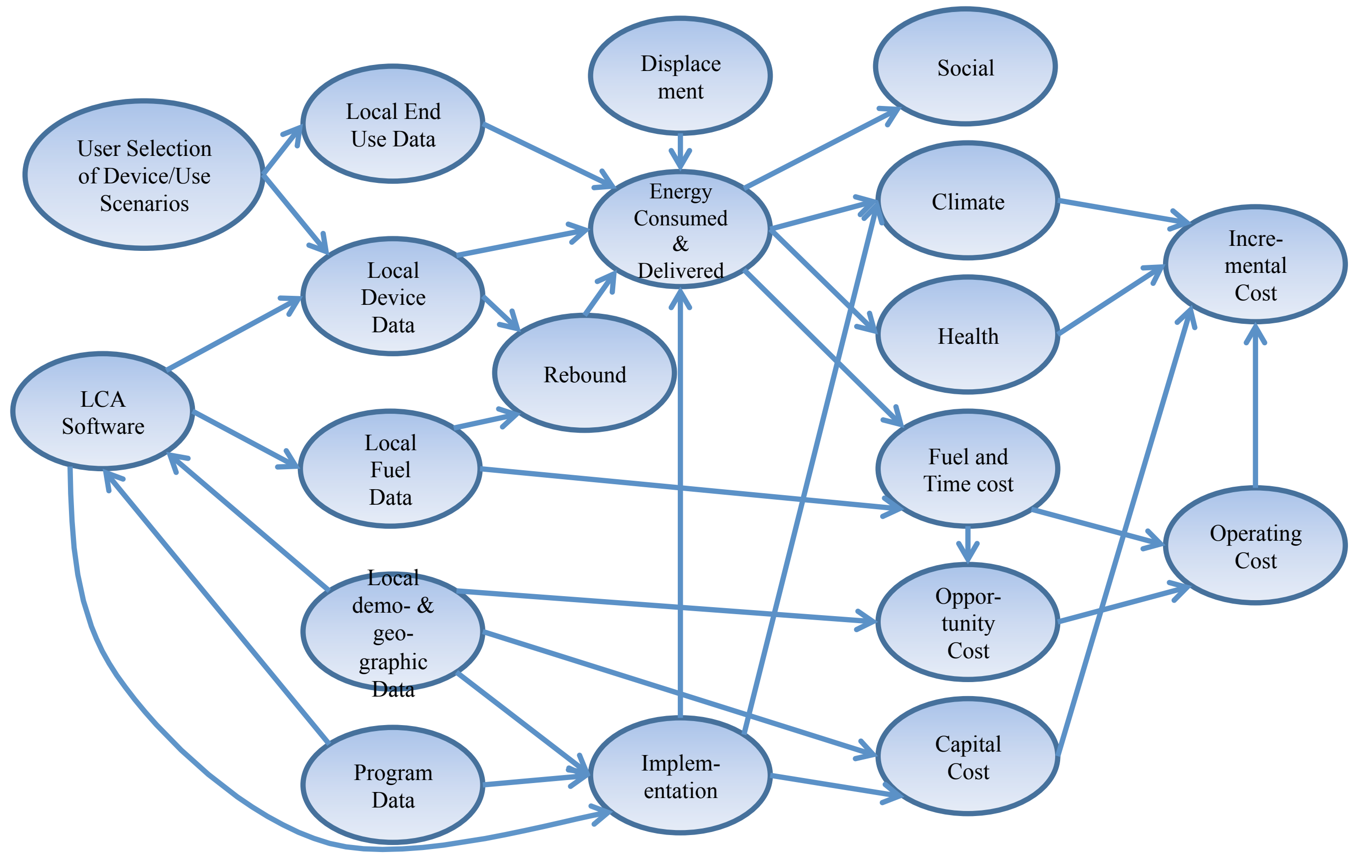


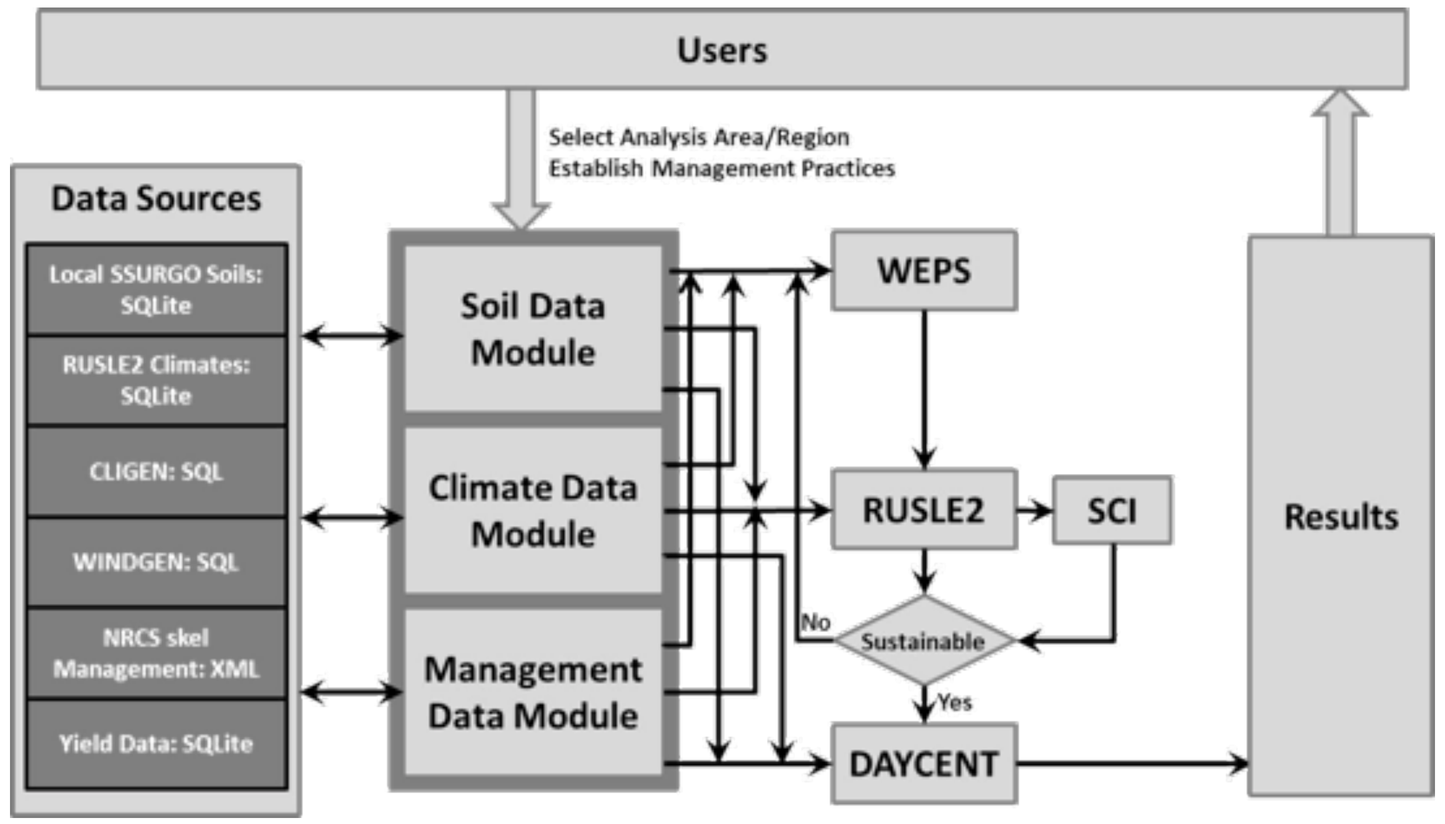
Update and increase the detail as needed

- What is the tradeoff between cost, acceptance, and impact for a particular geometry change to an energy technology?
- How do I maximize the impact of the energy system?
- If I change materials what will be impact of the on the environment and the people?

Design questions







Components

- Cookstoves
- Solar hot water
- Lights

+

Village Energy Model

- Rebound
- Climate impacts
- User acceptance

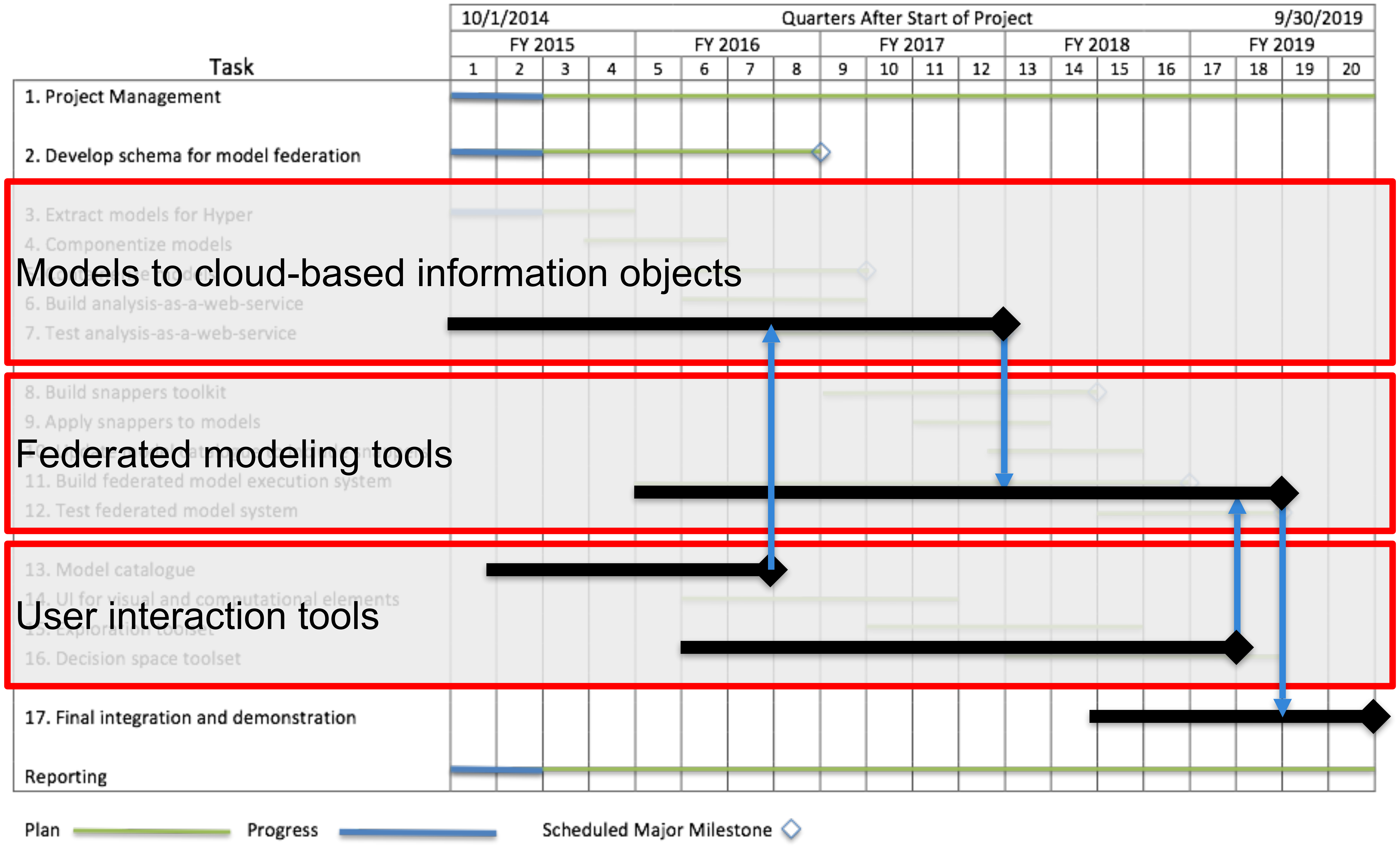
+

Agronomic Model

- Erosion
- Fertility
- Crop yield

Systems level design

	Current Practice	Proposed
Software	Libraries	Web-enabled microservices
Language	Specific (overcome with cross-compilers)	Agnostic
Integration Cost	High	Low
Data re-use	Not implicit	Implicit
Latency	Designed to be low	Can be higher (needs to be addressed)


10/1/2014
Quarters After Start of Project
9/30/2019
FY 2015
FY 2016
FY 2017
FY 2018
FY 2019
Task
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
1. Project Management
2. Develop schema for model federation
3. Extract models for Hyper
4. Componentize models
Models to cloud-based information objects
6. Build analysis-as-a-web-service
7. Test analysis-as-a-web-service
8. Build snappers toolkit
9. Apply snappers to models
Federated modeling tools
11. Build federated model execution system
12. Test federated model system
13. Model catalogue
User interaction tools
16. Decision space toolset
17. Final integration and demonstration
Reporting
Plan
Progress
Scheduled Major Milestone

Work Plan

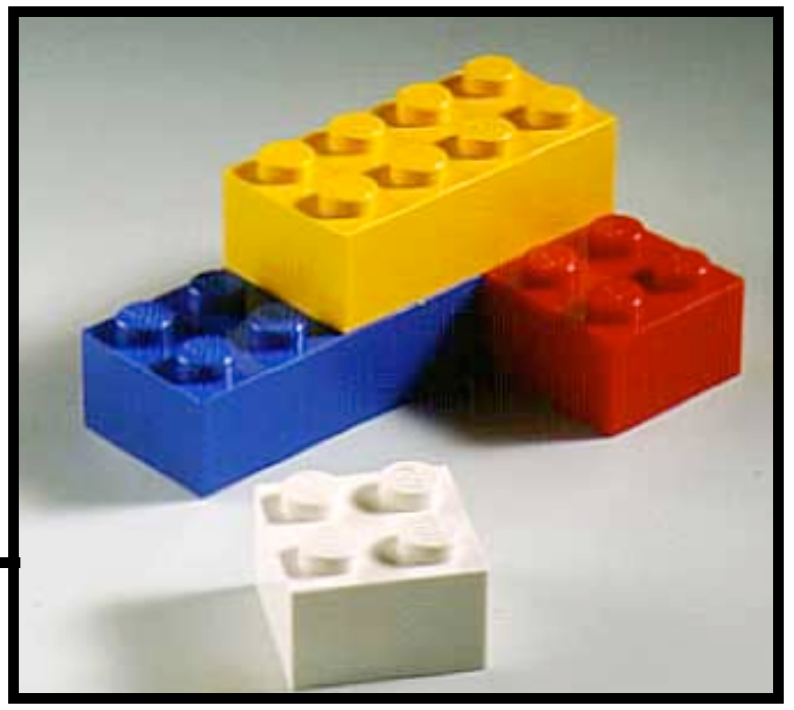
Models to cloud-based information objects

- Complete establishing a separable model set for the NETL Hyper facility
- Developed and implemented the needed linking schema for a simple energy problem
- Outlined the schema needed to link models together using a peer-to-peer ontology

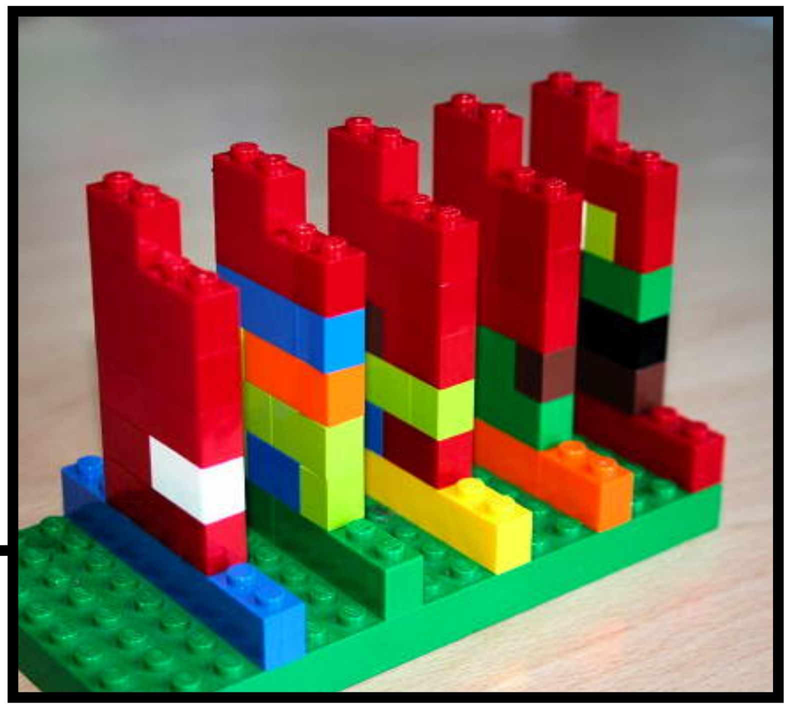
User interaction tools

- Chose Unity™ as the user interaction environment
- Initiated development of a simple example based on “hand crafted” connection points

Snap



Build



Do

New modeling paradigm

Decision making environments that integrate all the information, models, and other artifacts related to a product or process.

Goal

Current and former PhD students

Dan Bell	Balu Karthikeyan
Steve Corns	Nordica MacCarty
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Steven Gent	David Muth
Gengxun Huang	Zach Reinhart
Nate Johnson	Sunil Suram
Peter Johnson	Aditya Velivelli

Collaborators

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Prof. Tom Shih

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