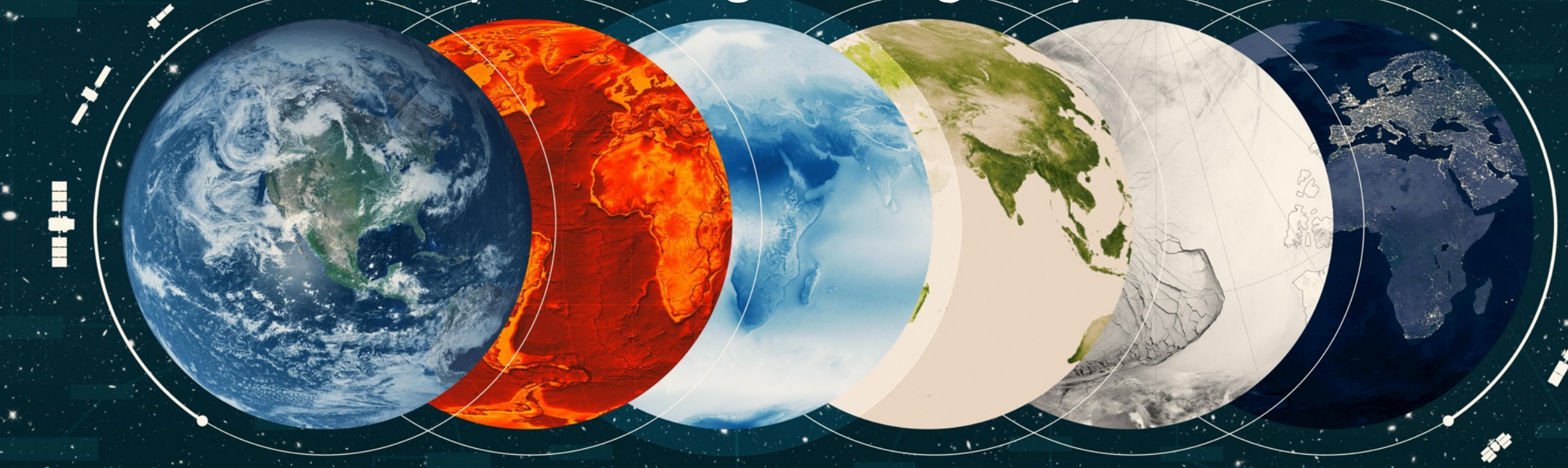
Science systems engineering for planet earth

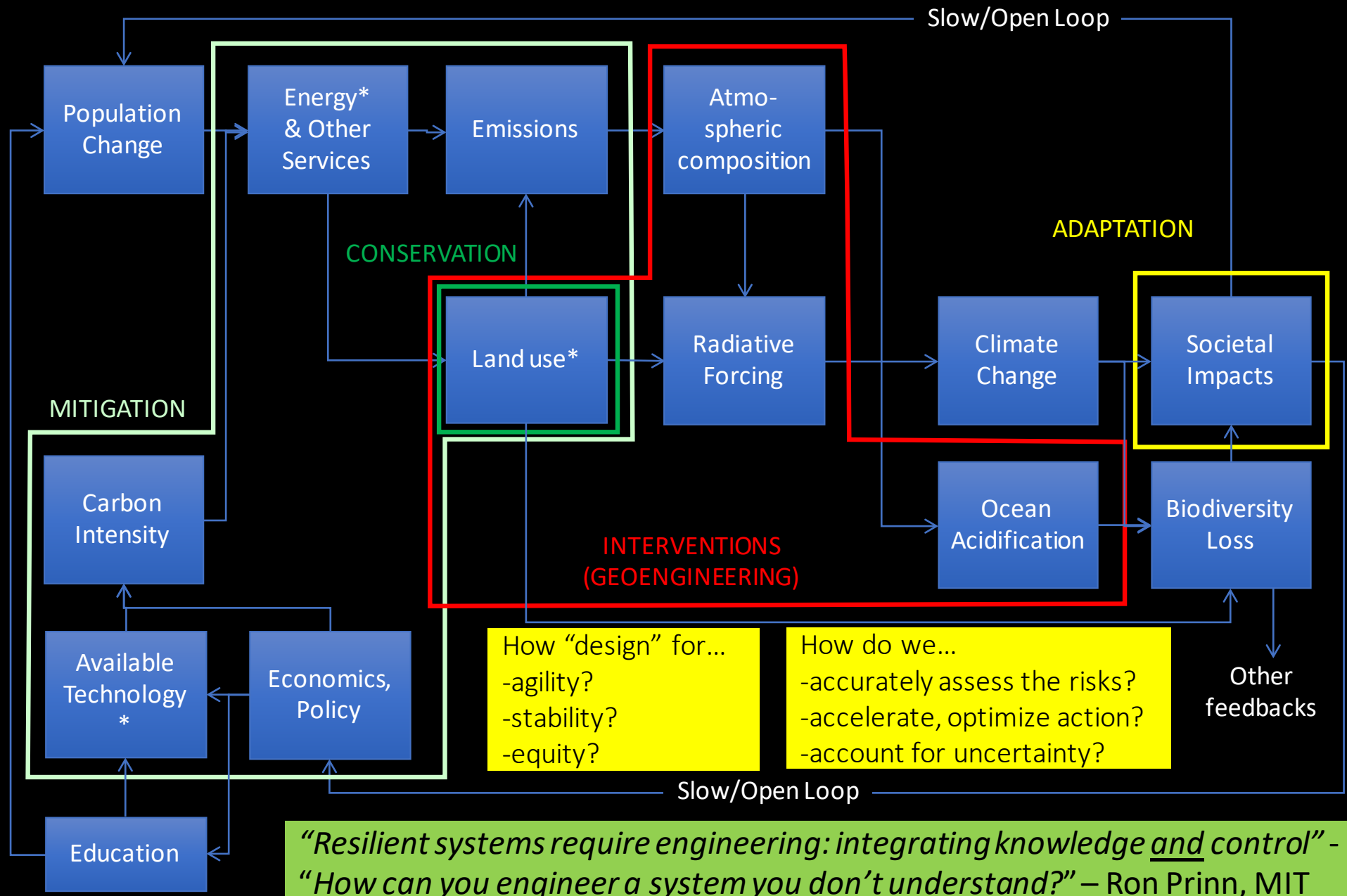


Riley Duren

Research Scientist, University of Arizona

Engineering Fellow, NASA Jet Propulsion Laboratory

Which system? The global change system



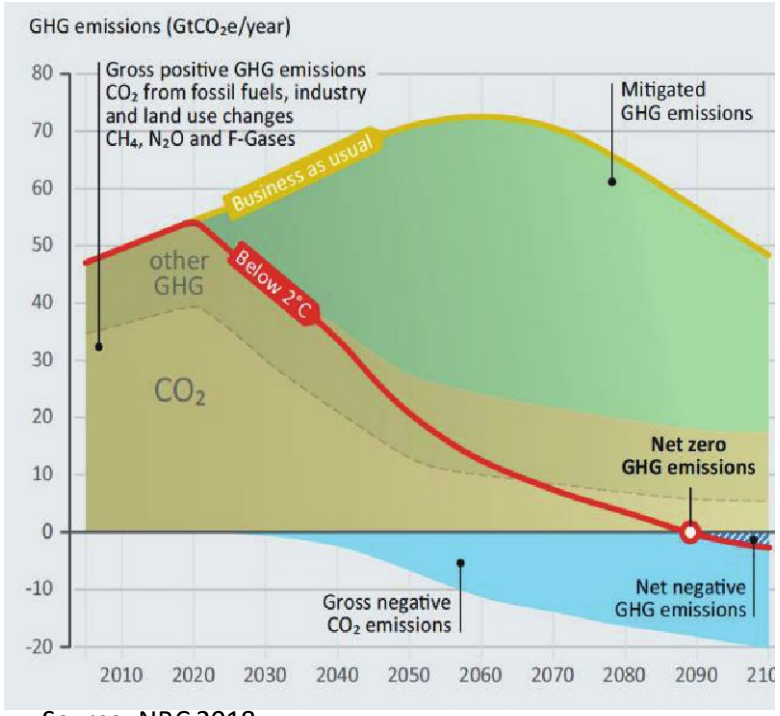
*perceived focus for engineering

"Resilient systems require engineering: integrating knowledge and control" - Me

"How can you engineer a system you don't understand?" – Ron Prinn, MIT

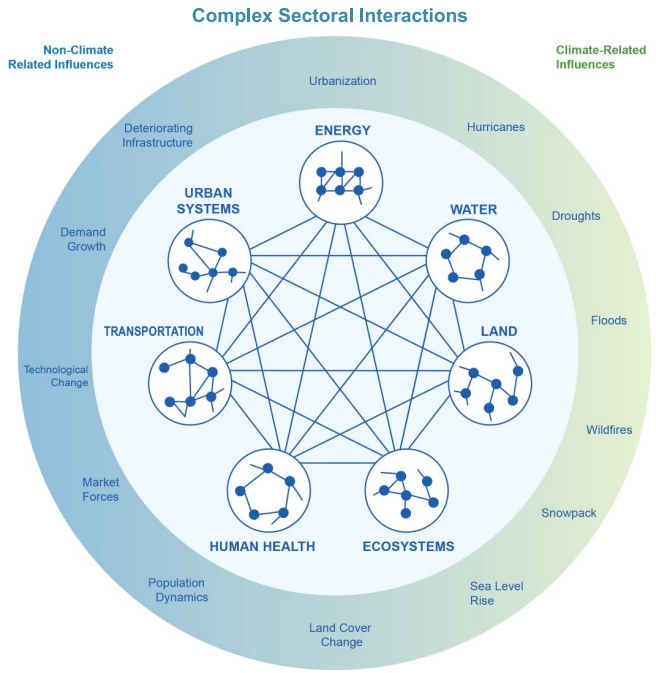
Managing the climate action “mission”

Mitigation & Negative Emissions



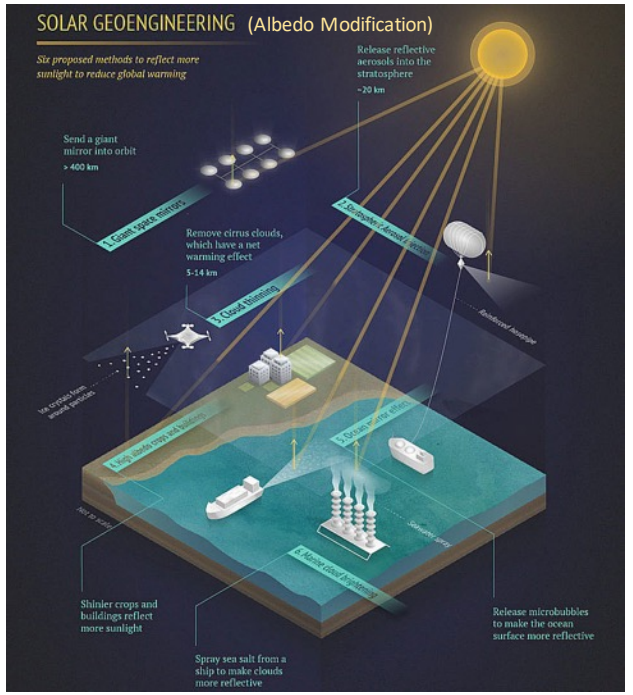
Source: NRC 2018

Adaptation



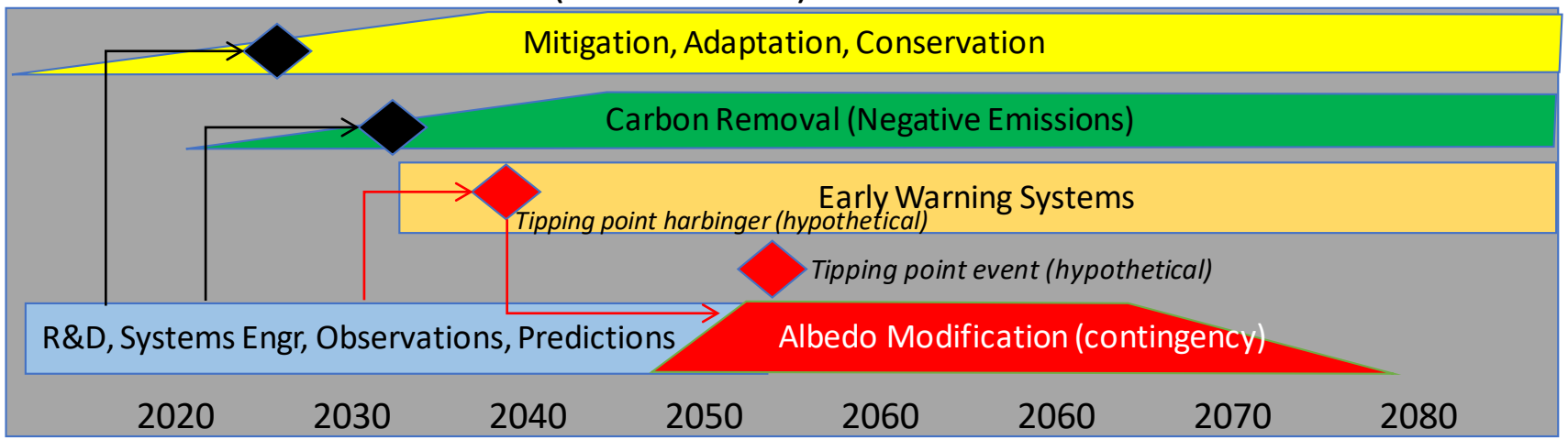
Source: NCA 2018

Direct Interventions



Source: Rosamund Pearce/Carbon Brief

Timeline (one scenario)



Key decision points
(ongoing operational decisions)

Key decision points
(potential planetary emergency)

This system of systems (mission) requires engineering

Observations

- Earth science has very broad scope but generally incomplete integration of natural and human systems and still has more of a knowledge than control focus

- Active management of the coupled human-earth system mostly occurs at smaller scales – but with considerable variation in technical capacity, resources and connectivity

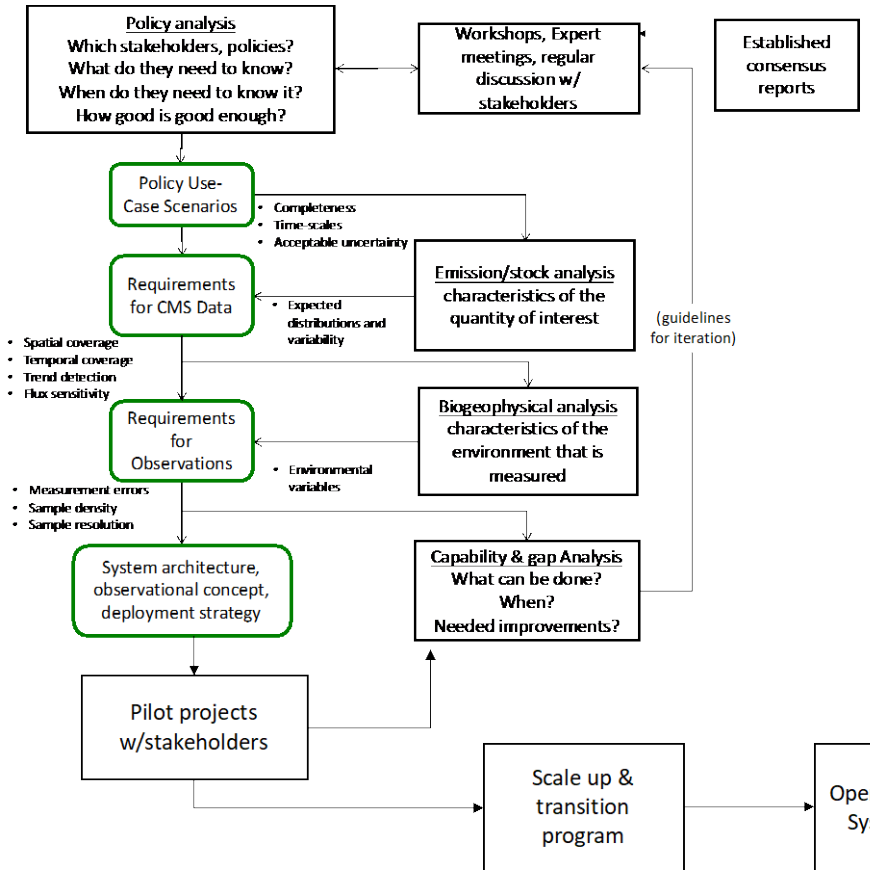
- Systems Engineering evolved to manage complexity & integrate large human systems but mostly *disconnected from earth science* other than delivering tech (satellites, computing)

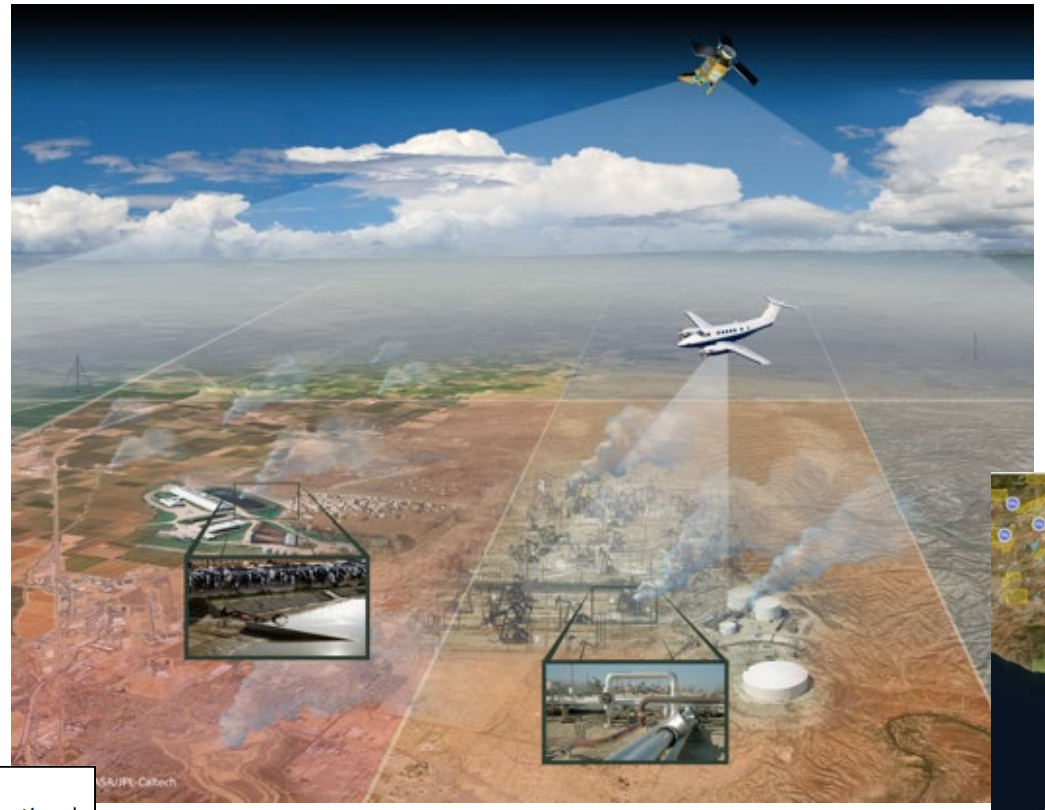
- Persistent institutional and cultural barriers – "socio-thermodynamics"
  - Governance: short interest-horizons and lack of agility
  - Discipline stove-piping
  - Workforce: training and opportunities
  - Misperception of engineers as (just) technologists

Properly formulated programs with a "mission focus" could address these gaps

Methane Monitoring System of Systems

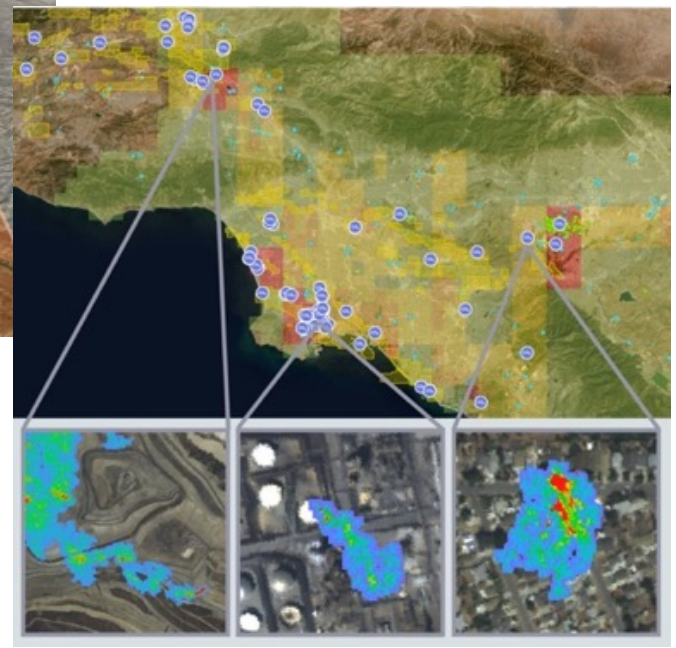
Systems engineering, carbon science, multi-scale observations, fusion, data science, stakeholder entrainment





Super-emitters responsible for 30-50% of methane budget

Pilot project led to mitigation of >3% of California methane inventory (and counting)



Operational scale-up is possible with sufficient prioritization

Planetary Situational Awareness System

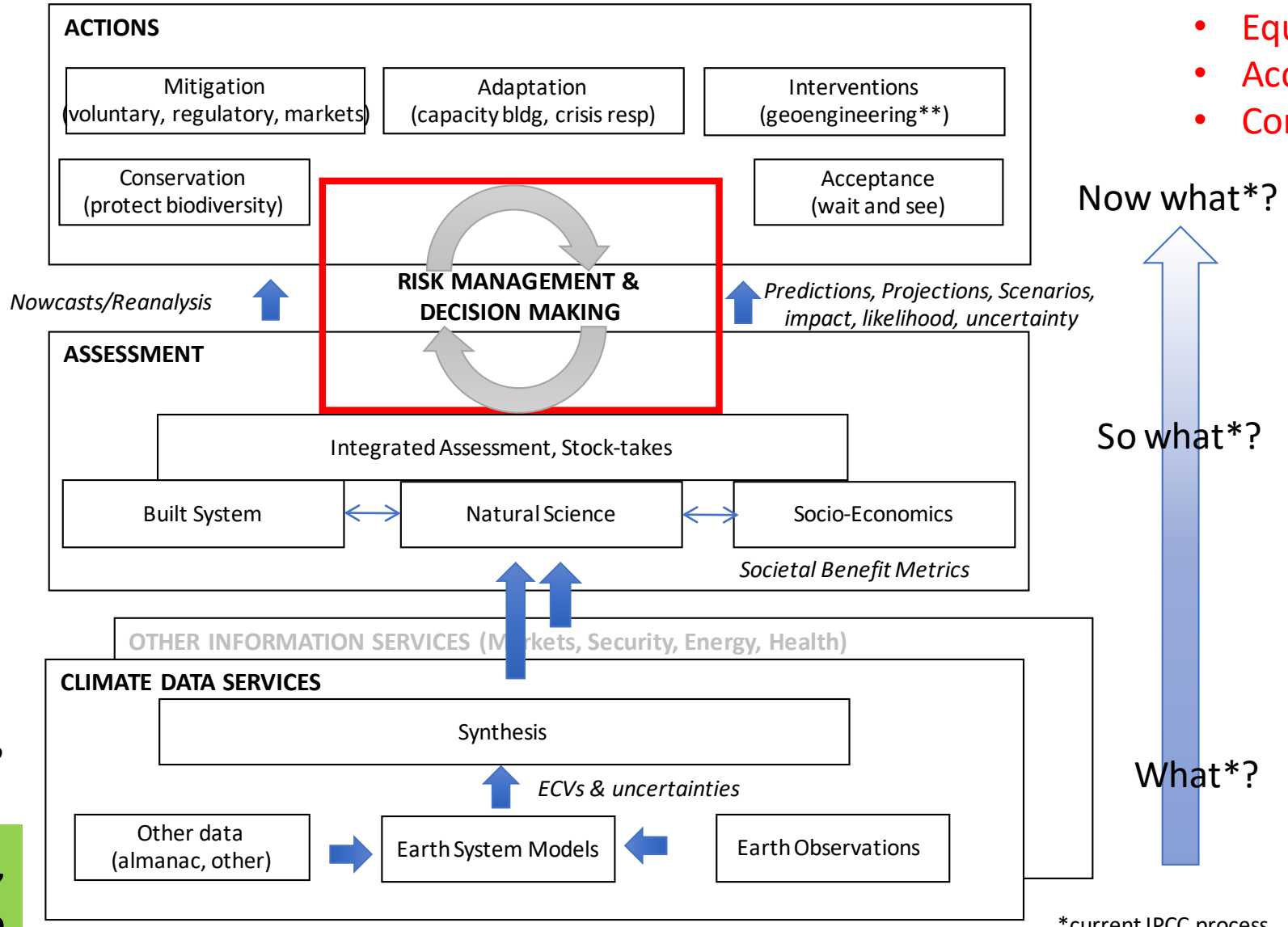
Common challenges
- Latency
- Transparency
- Equity
- Accuracy
- Completeness

What can be Done (action space)?

What do we need to Know? (& how well)

Requirements

How do we get the information?



Now what*?

So what*?

What*?

*current IPCC process (5+ yr latency)

**negative emissions &/or albedo modification

Need science-based, <u>engineered</u> system

Recommendations

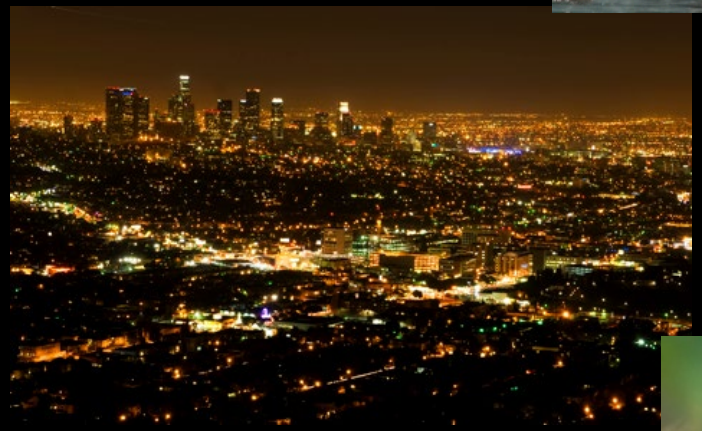
- Organization: balance basic research with programs that require *integrated* science/engineering teams focused on earth system resiliency as a *mission*

- Scaling: embrace *scalability* as a program priority; engage engineers earlier and establish a pool of funding to transition successful pilot projects to operational frameworks

- Culture: acknowledge and confront institutional gaps and disciplinary priors
  - Bio-geophysics is easy, "*socio-thermodynamics*" is hard
  - Control system perspective (knowledge and control)
  - Uncertainty quantification and active risk management
  - Balancing ambition and humility

- Training: New curricula and work-study in "science systems engineering" to integrate across traditional boundaries (natural science, social science, engineering) *operationally*

One planet, one discipline: Earth System Science and Engineering



Thank you

http://methane.jpl.nasa.gov