Antidisciplinary: Tackling the technical and social challenges to data science-driven discovery

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Abstract

Data science refers to the set of tools, technologies, and teams that alter the paradigm by which data are collected, managed and analyzed. Data science is, therefore, decidedly broader than 'machine learning,' and includes instead the full data lifecycle. Never has the need for effective data science innovation been greater than now when at every turn data-driven discovery is both burdened and invigorated by the growth of data volumes, varieties, veracities, and velocities. This growing scale of science requires dramatic shifts in collaborative research, requiring projects to climb the gradations of collaboration from unidisciplinary, to multi-, inter-, and transdisciplinary (Figure 1, [Hall et al., 2014; NRC, 2015]), and perhaps even to an entirely new level that defies any traditional boundary, or antidisciplinary (https://joi.ito.com/weblog/2014/10/02/antidisciplinar.html). We will discuss the cutting-edge efforts advancing collaborative research in Space Physics and Aeronomy, highlight progress, and synthesize the lessons to provide a vision for future innovation in data science for Heliophysics. We will specifically focus on three trail-blazing initiatives: 1) the NASA Frontier Development Laboratory; 2) the HelioAnalytics group at the Goddard Space Flight Center in cooperation with the NASA Jet Propulsion Laboratory's Data Science Working Group; and 3) an International Space Sciences Institute project. References: Hall, K.L., Stipelman, B., Vogel, A.L., Huang, G., and Dathe, M. (2014). Enhancing the Ef- fectiveness of Team-based Research: A Dynamic Multi-level Systems Map of Integral Factors in Team Science. Presented at the Fifth Annual Science of Team Science Confer- ence, August, Austin, TX. NRC (National Research Council) (2015). Enhancing the Effectiveness of Team Science. Washington, DC: The National Academies Press. https://doi.org/10.17226/19007.

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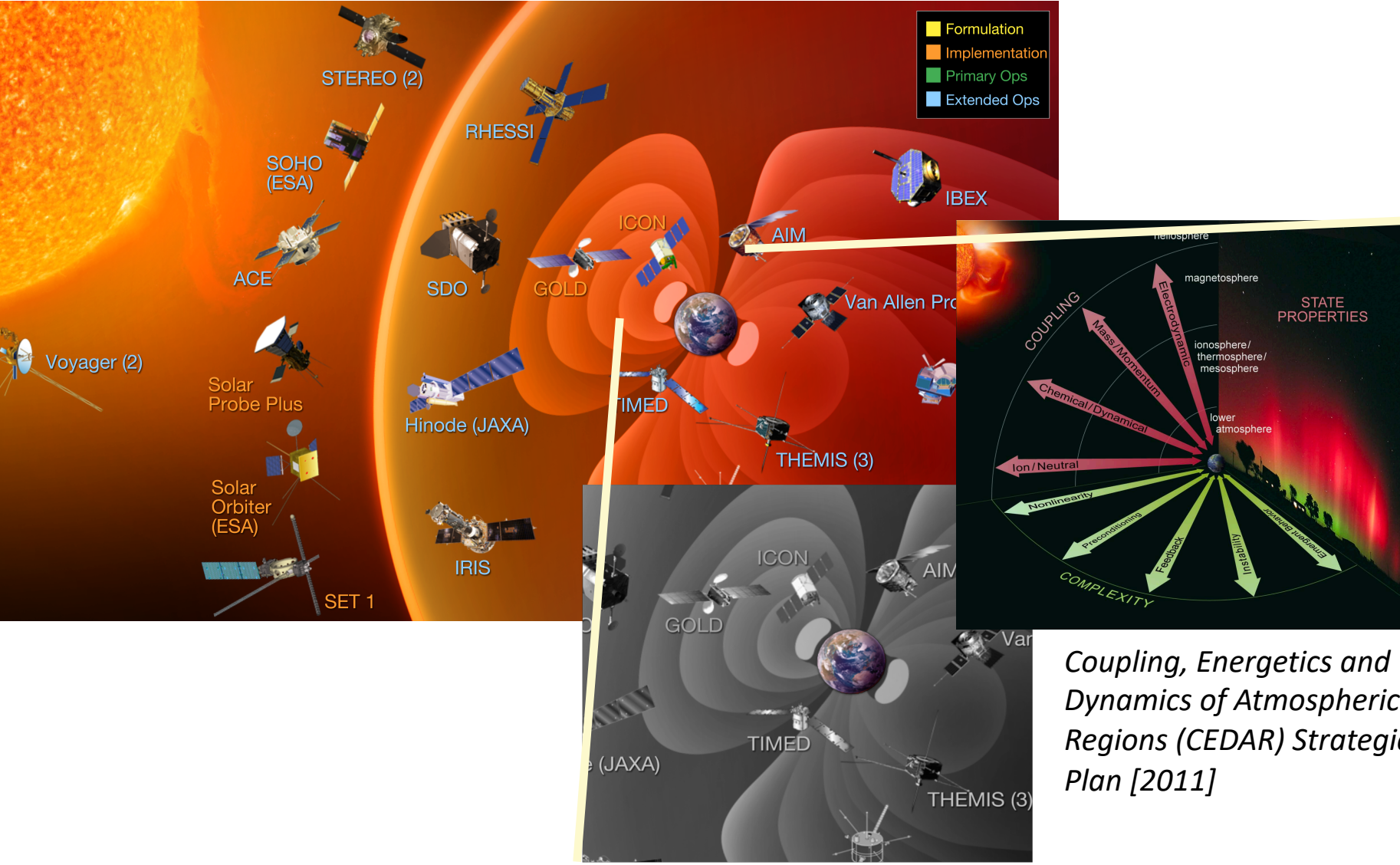Rich Doyle
Madhulika Guhathakurta
Enrico Camporeale

'The most fruitful areas for the growth of the sciences were those which had been neglected as a no-man's land between the various established fields.'

-Norbert Weiner

Society's greatest science and social challenges and the capabilities of our approaches to address them are in a constant tug-of-war, the challenges dictating new responses and the approaches attempting to counteract. We are at a pivotal moment in this state of tension in which the scale of the challenges have outstripped our approaches to solve them. New scales of collaboration are needed to create flourishing scientific and societal communities.
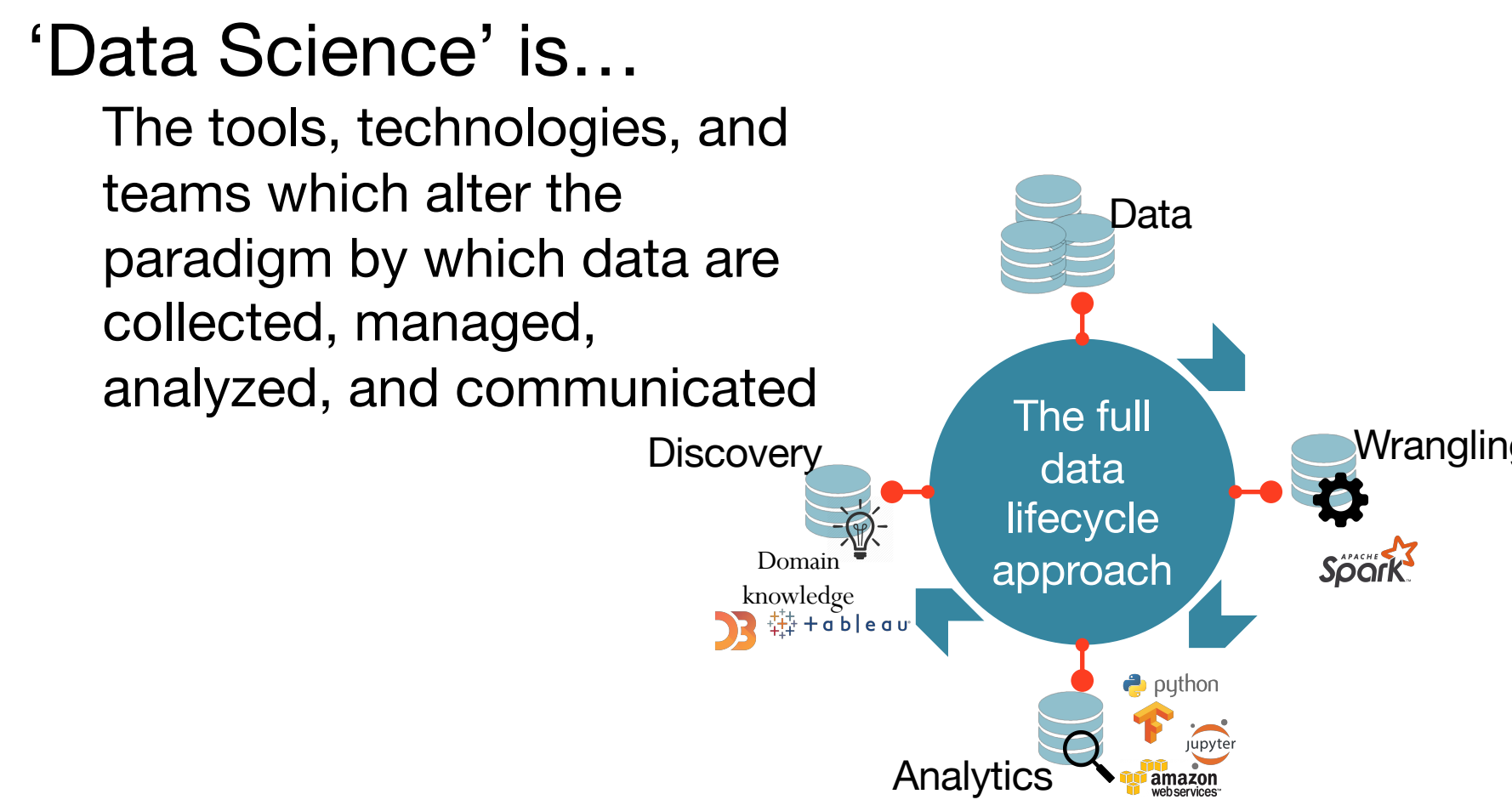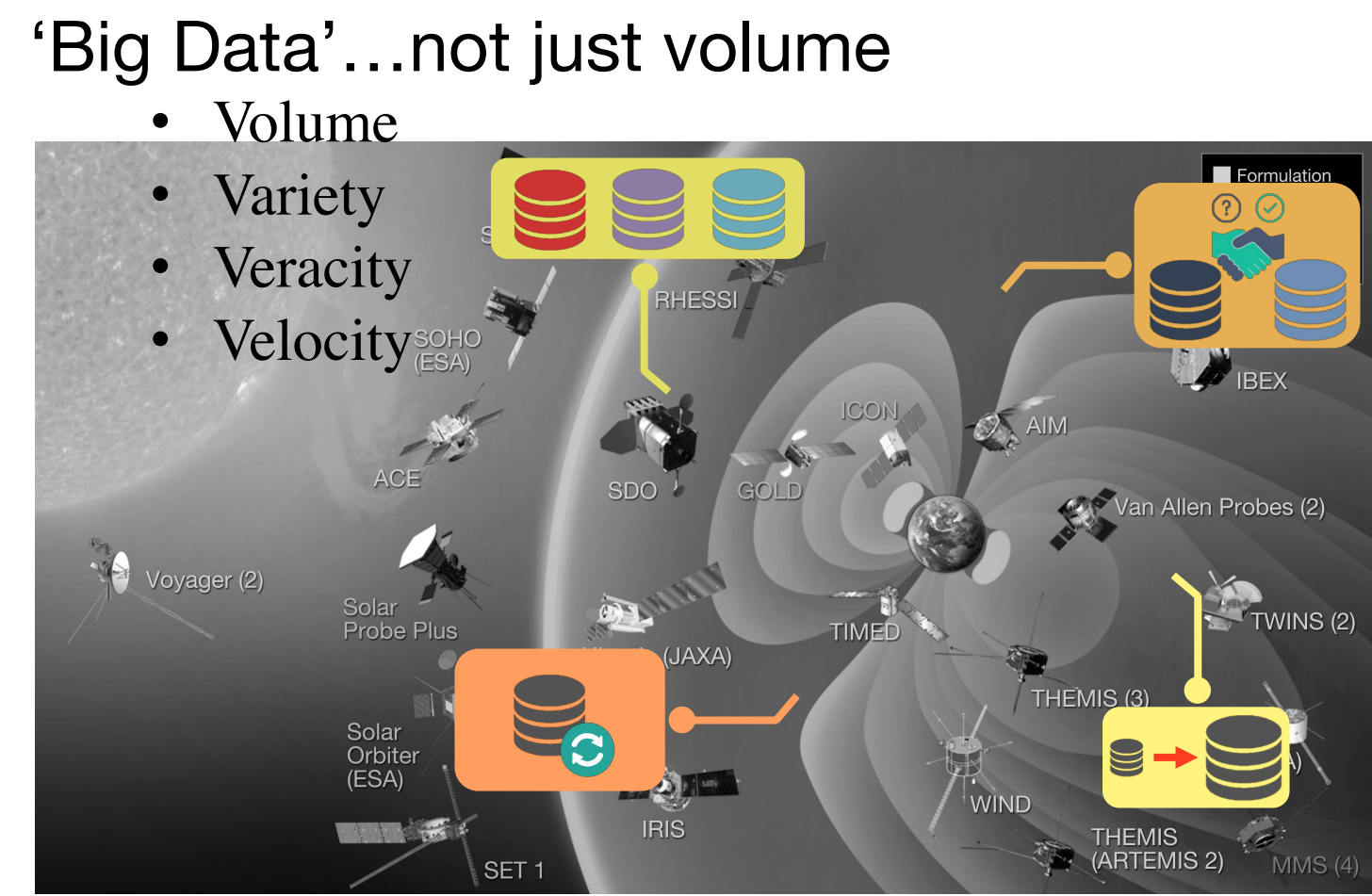
How do you collaborate? How do you forge new collaborations? What prevents you from effective collaboration?

This poster illustrates cutting-edge efforts advancing collaborative research in Space Physics and Aeronomy and emerges a new model of collaboration: antidisciplinary. The intent is to create a vision and a conversation, *not* to be a definitive outcome.

The Context:

Space physics…a *tipping point*

Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR) Strategic Plan [2011]

The Method:

Data science provides the tools for the data and collaboration challenges

'Big Data'…not just volume
- Volume
- Variety
- Veracity
- Velocity

'Data Science' is…
The tools, technologies, and teams which alter the paradigm by which data are collected, managed, analyzed, and communicated
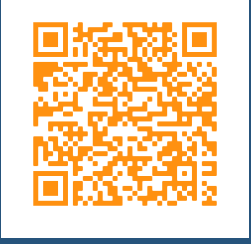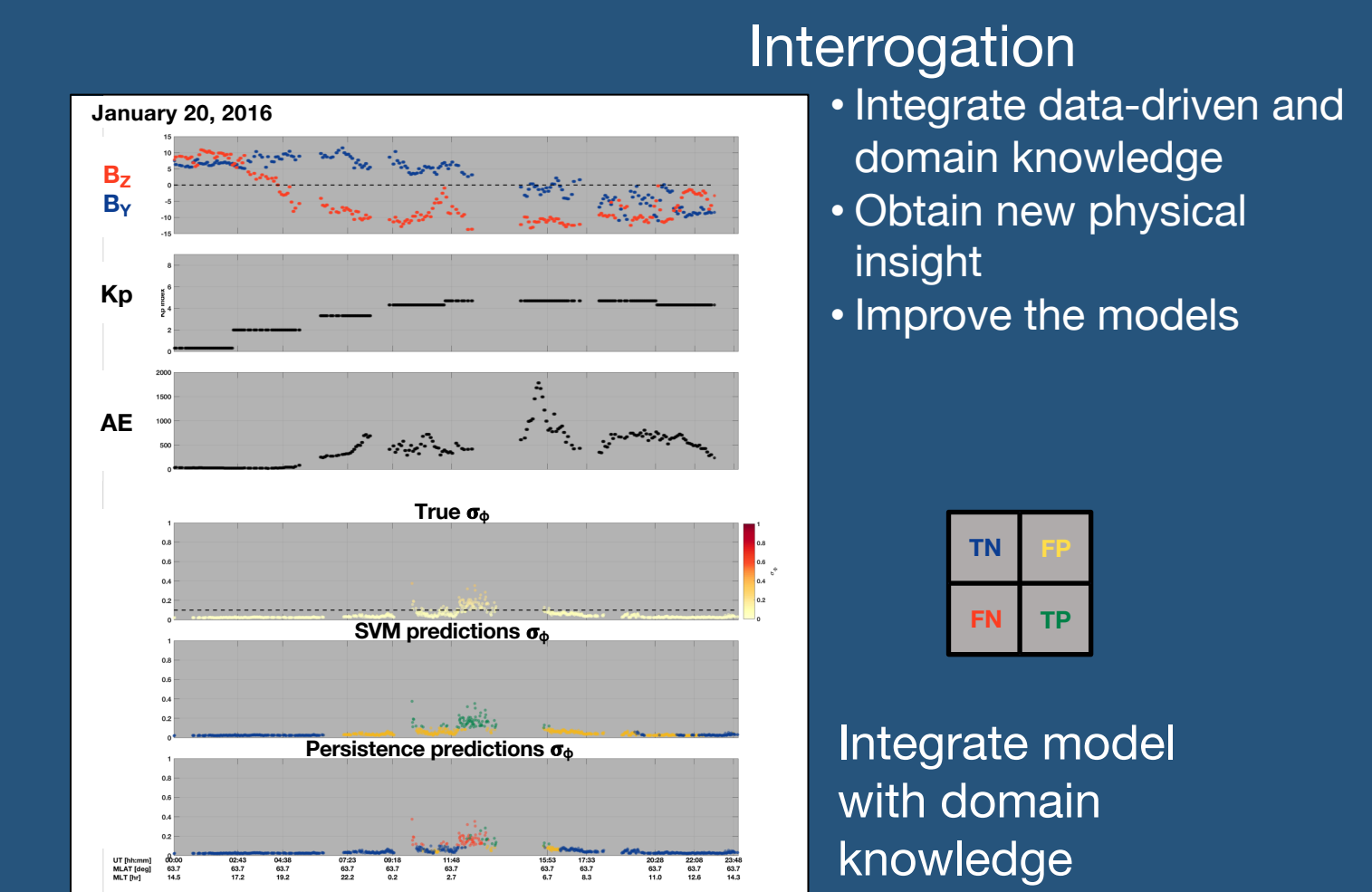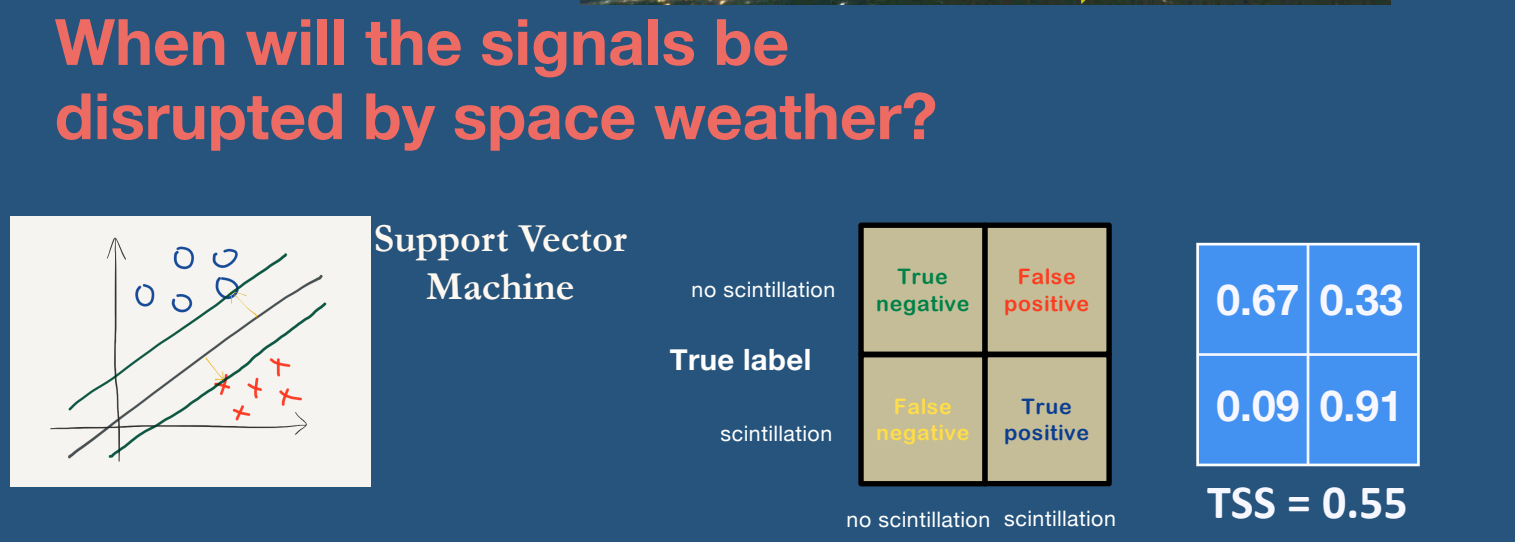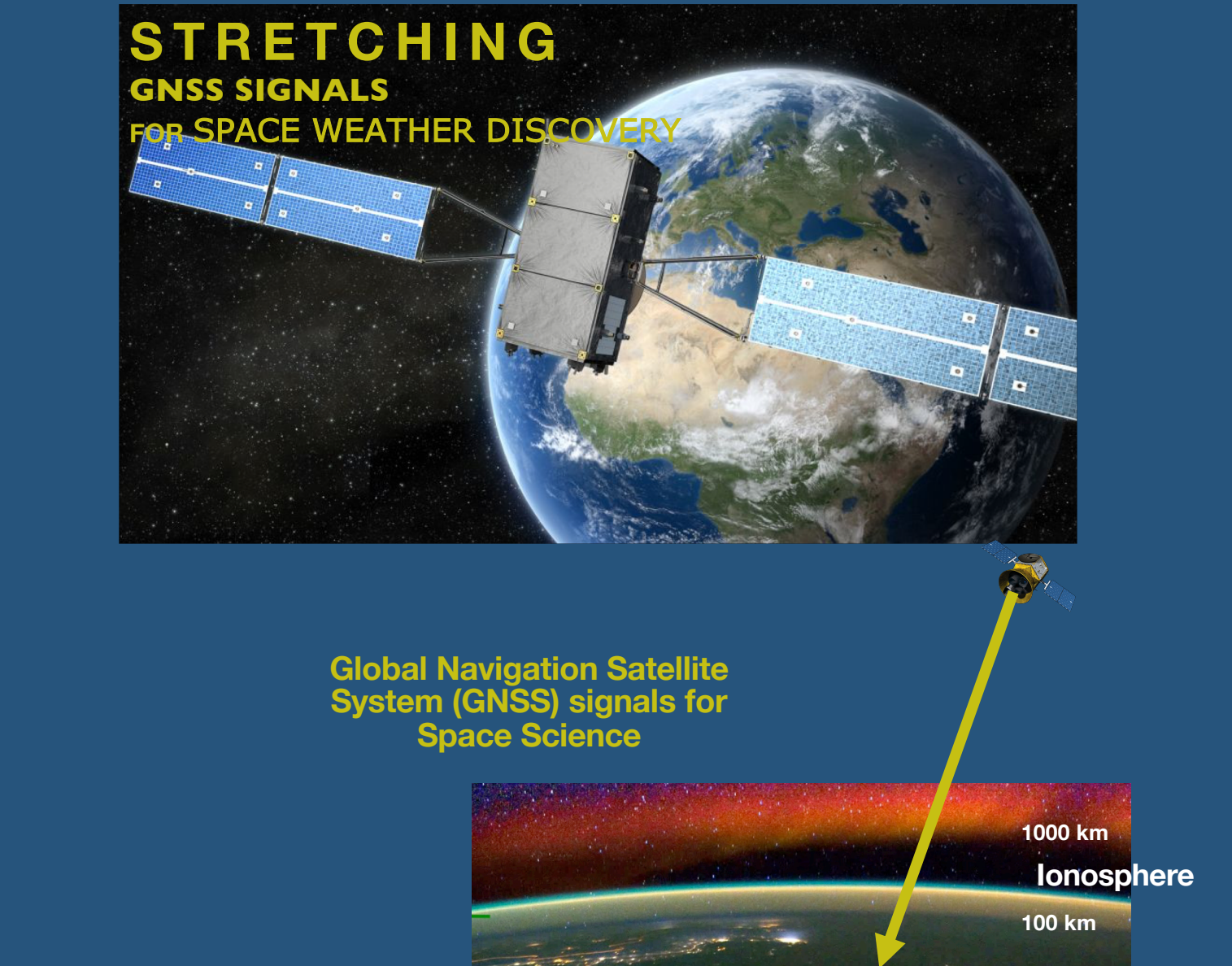

A vision for a *flourishing* space physics community

The growing scale of space science requires *radically* new approaches spanning data science and collaboration

Cross-Institution
NASA Digital Transformation and trans-center data science

Meeting NASA challenges across the full mission-science data lifecycle
Scaling pressures for NASA Missions and data analyses coupled with increasing competition with 'digital first' companies require transformation

In space physics…
The first space weather pilot program in the JPL Data Science Working Group, grown across NASA centers to the Goddard Space Flight Center
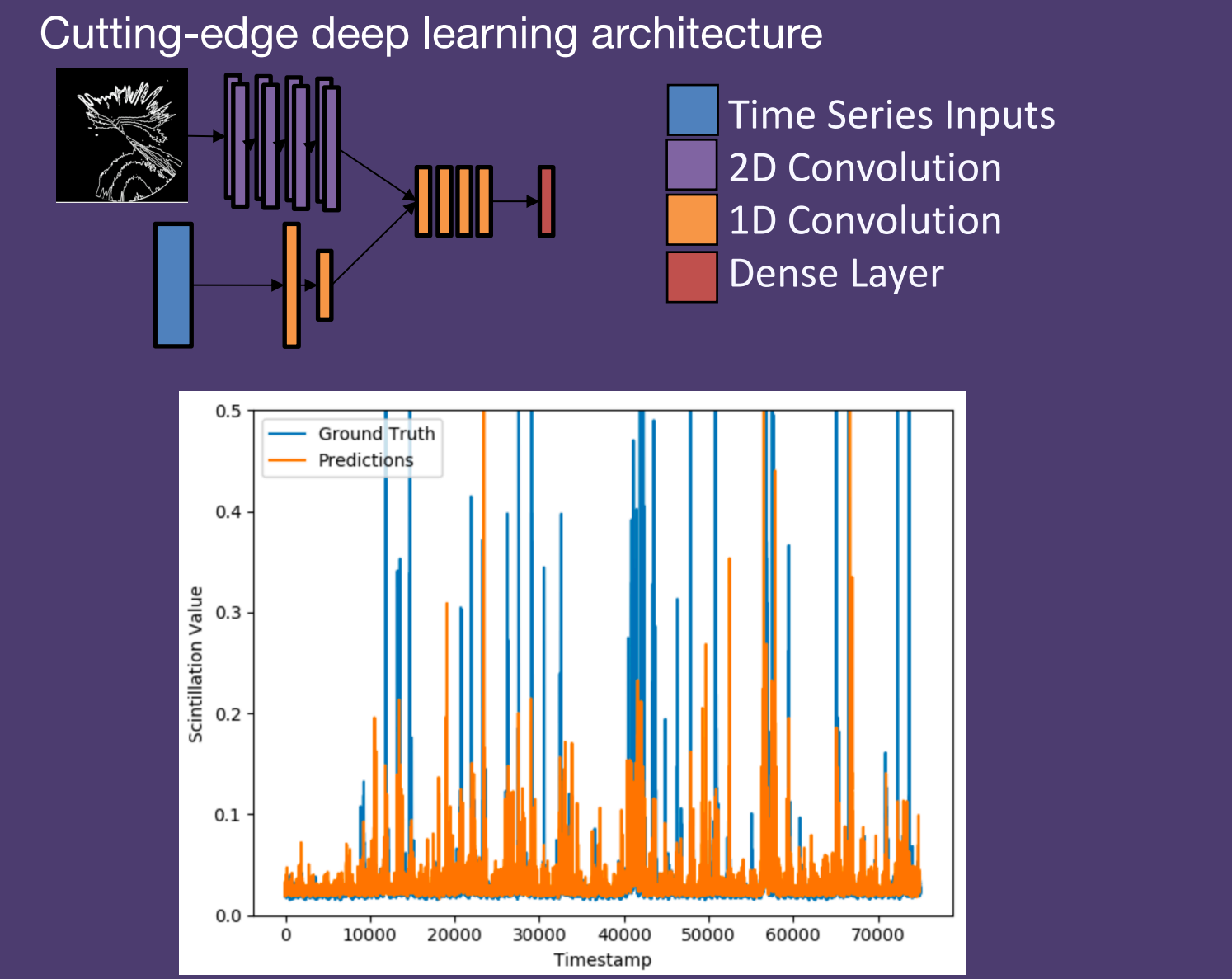

STRETCHING GNSS SIGNALS for SPACE WEATHER DISCOVERY

Global Navigation Satellite System (GNSS) signals for Space Science

1000 km Ionosphere 100 km

When will the signals be disrupted by space weather?

Support Vector Machine

	no scintillation	scintillation	
True label	True negative	False positive	0.67 / 0.33
	False negative	True positive	0.09 / 0.91
	no scintillation	scintillation	TSS = 0.55
	Predicted label		

Interrogation

January 20, 2016
- Integrate data-driven and domain knowledge
- Obtain new physical insight
- Improve the models

Integrate model with domain knowledge

Cross-Sector
NASA Frontier Development Lab

Deep Learning meets Deep Science
The Frontier Development Laboratory is a research and development incubator cultivated by a *public-private partnership* between NASA, Silicon Valley, and private space

In space physics…
FDL 2019 Space Weather team used foundation data and infrastructure and added ground-based auroral imagery data and machine learning sophistication (cutting-edge neural networks and advanced optimization metrics) to extend the capability
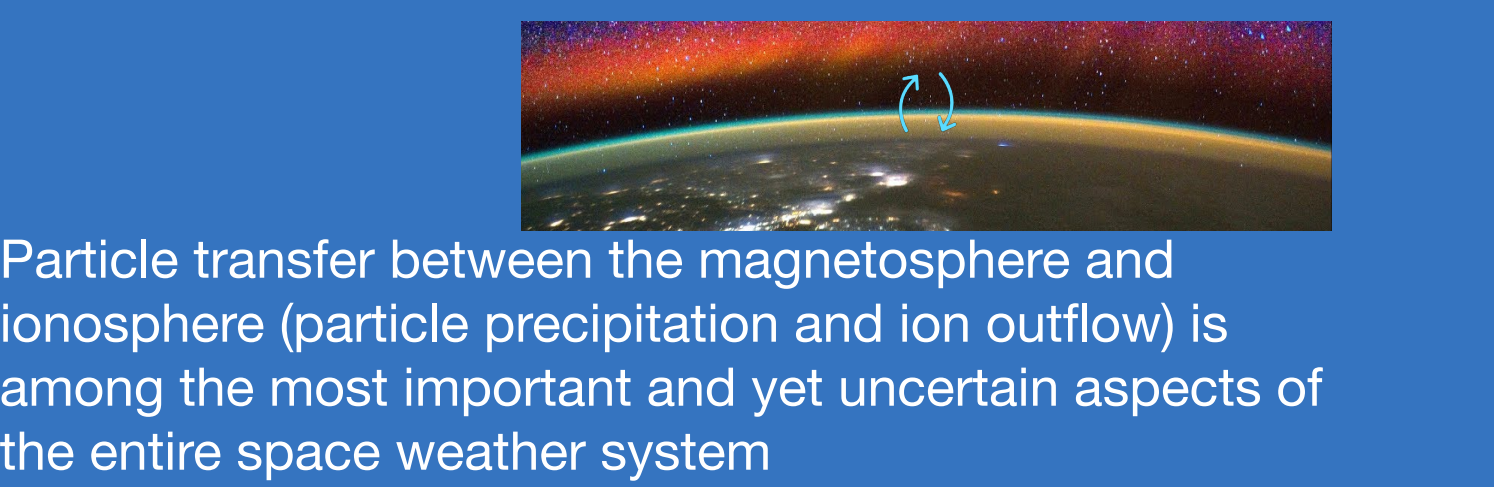
Aurora are correlated with GNSS disruption
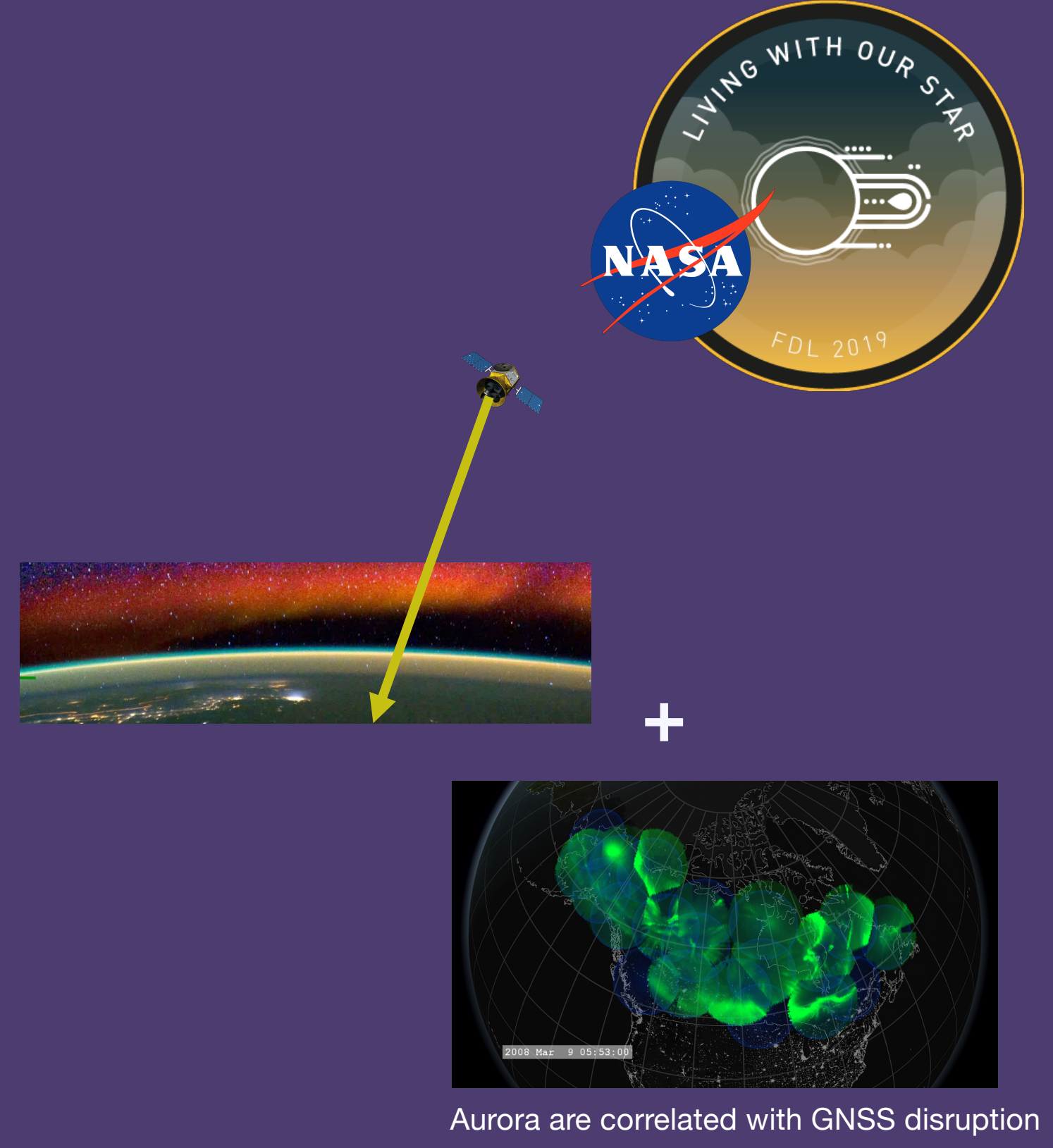
Can sophisticated deep learning techniques grow the capability to predict GNSS disruptions?

Cutting-edge deep learning architecture

- Time Series Inputs
- 2D Convolution
- 1D Convolution
- Dense Layer

Ground Truth / Predictions

Cross-Nation
The International Space Sciences Institute

Operator of Interdisciplinarity
Institute of advanced study that cultivates a unique international multi-setting to reach out for new scientific horizons

In space physics…
2019 ISSI team brought together international contingent, space physics domain knowledge, data science, and innovative collaboration techniques to make progress on a long-standing challenge in space weather – predicting the particle precipitation environment

Particle transfer between the magnetosphere and ionosphere (particle precipitation and ion outflow) is among the most important and yet uncertain aspects of the entire space weather system

Can improved collaboration produce models of particle precipitation commensurate with space weather needs?

Community of Practice

IMF / AE Index

State-of-the-art model / Next generation model
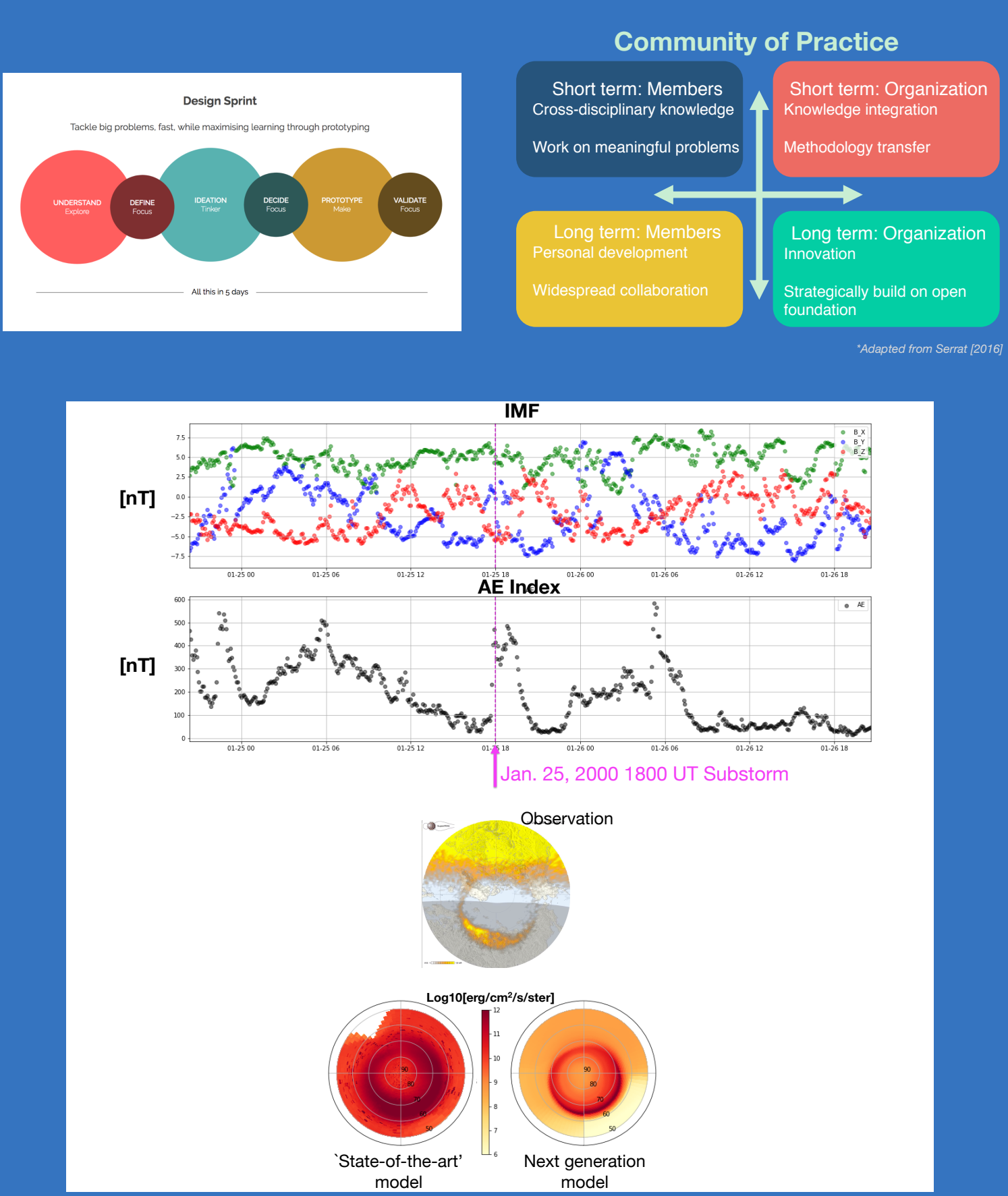
Come to the full ISSI space weather poster Wednesday 8-10 AM: "Novel approaches to geospace particle transfer in the digital age: Progress through data science"

The Product:

The antidisciplinary approach

Antidisciplinary is …

A term that has emerged from the MIT Media Lab referring to research that cannot be accomplished within any existing discipline. Instead, it requires: 1) explicit search for cross-cutting ideas and research agendas; 2) freedom to explore; and 3) departing from traditional rules
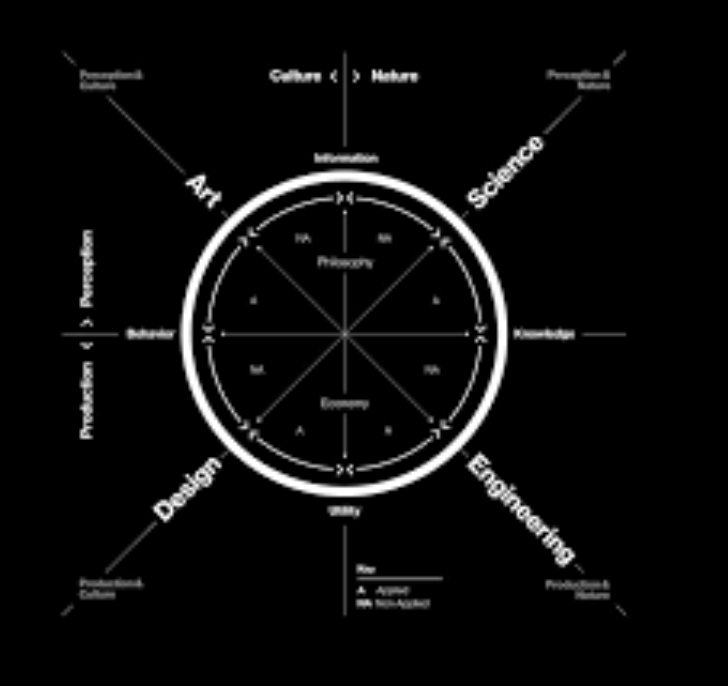
It defines a 'new cartography of the interrelation between these domains' [*Oxman, 2016; Journal of Design and Science (JoDS)*]

The antidisciplinary 'playbook':
- Practice #1: bring together the various communities to learn from each other through collaboration and experimentation → innovation explosion
- Practice #2: Involve those who know how to *share* and be open by default → build trust
- Practice #3: Move quickly from idealism to realism (deploy/demo) → beginner's mindset; closer working relationships around a set of incubator projects
- Practice #4: Move quickly from innovation to synthesis (different paces, timescales of impact and mindsets) → spring from accelerated learning stage to deep knowledge generation stage

The Action:

Help shape a flourishing space physics community

Town Hall!
Antidisciplinary: Science and engineering in the digital age

Join a *radically* interdisciplinary group to shape the New Frontier for the Earth and space sciences

Where:
Thursday, 12 December 2019; 18:15 - 19:15
Location: Moscone West, Room: 2003, L2

Abstract & Speakers: https://tinyurl.com/McGranaghan-AGU-TH-Github

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