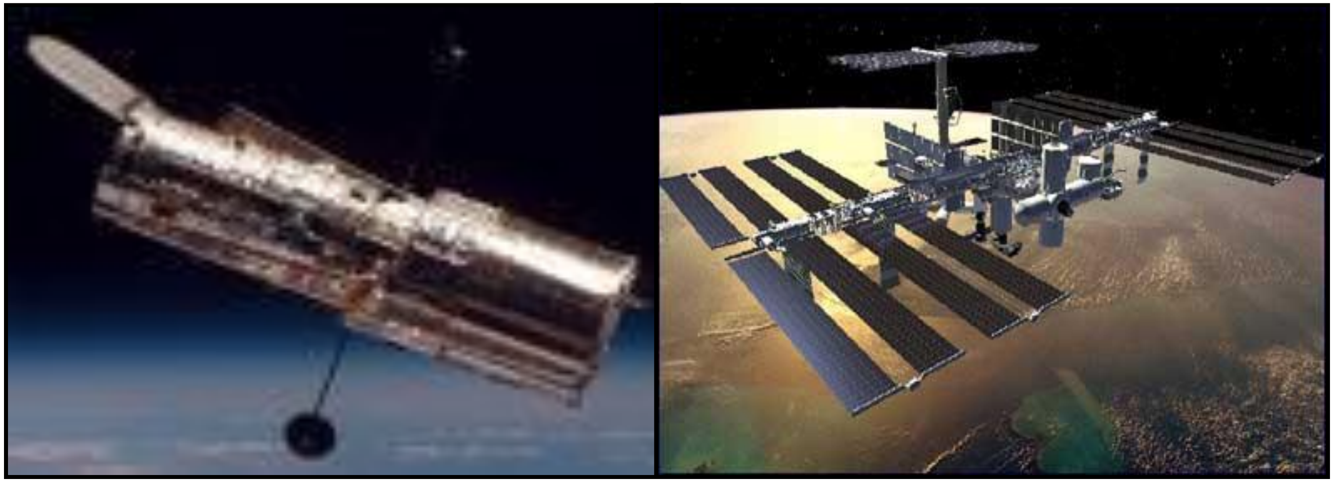
SABER ASTRONAUTICS

Next Generation of Space Control

Dr. Jason Held
Sydney Australia
+61 4 3317-8740
jheld@saberastro.com
saberastro.com

Where we come from



Based in Sydney, Boulder, CO USA

Prior work flight software on Hubble and ISS

Senior operators from USSTRATCOM

PhD graduates from world class robotics labs

+ a mature internship program
150 applicants per year

SABER ASTRONAUTICS

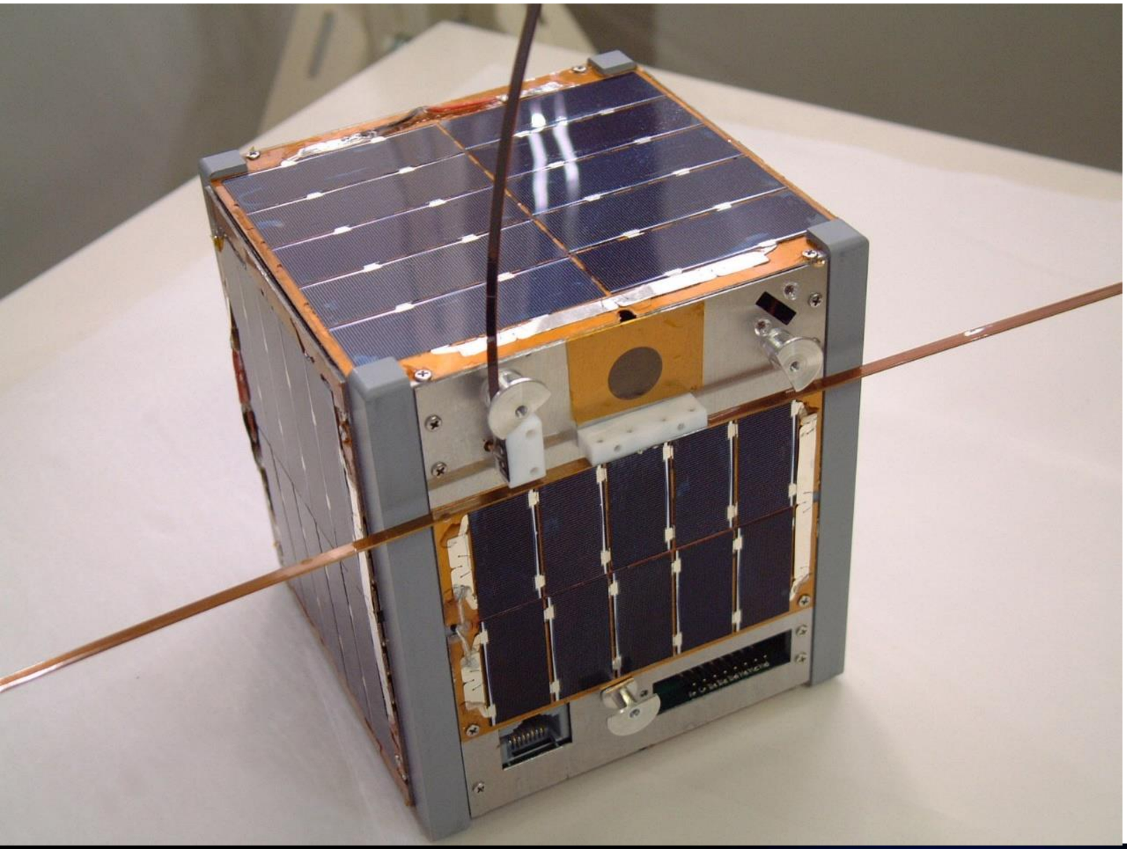
The Problem: Bespoke Software

Both in space and on the ground

Problem: Diagnostics

Because every minute of satellite downtime is millions in lost revenue

A single CubeSat has 100 health sensors



Effects:

- **Single Event Upsets**
- **False Positives**
- **Diagnostic Challenges**

What is the root cause of damage?

$2^{n(n-1)/2}$ causes

2^{4950} possibilities!

(sorry for the math folks. Lets just say "infinite" and move on)

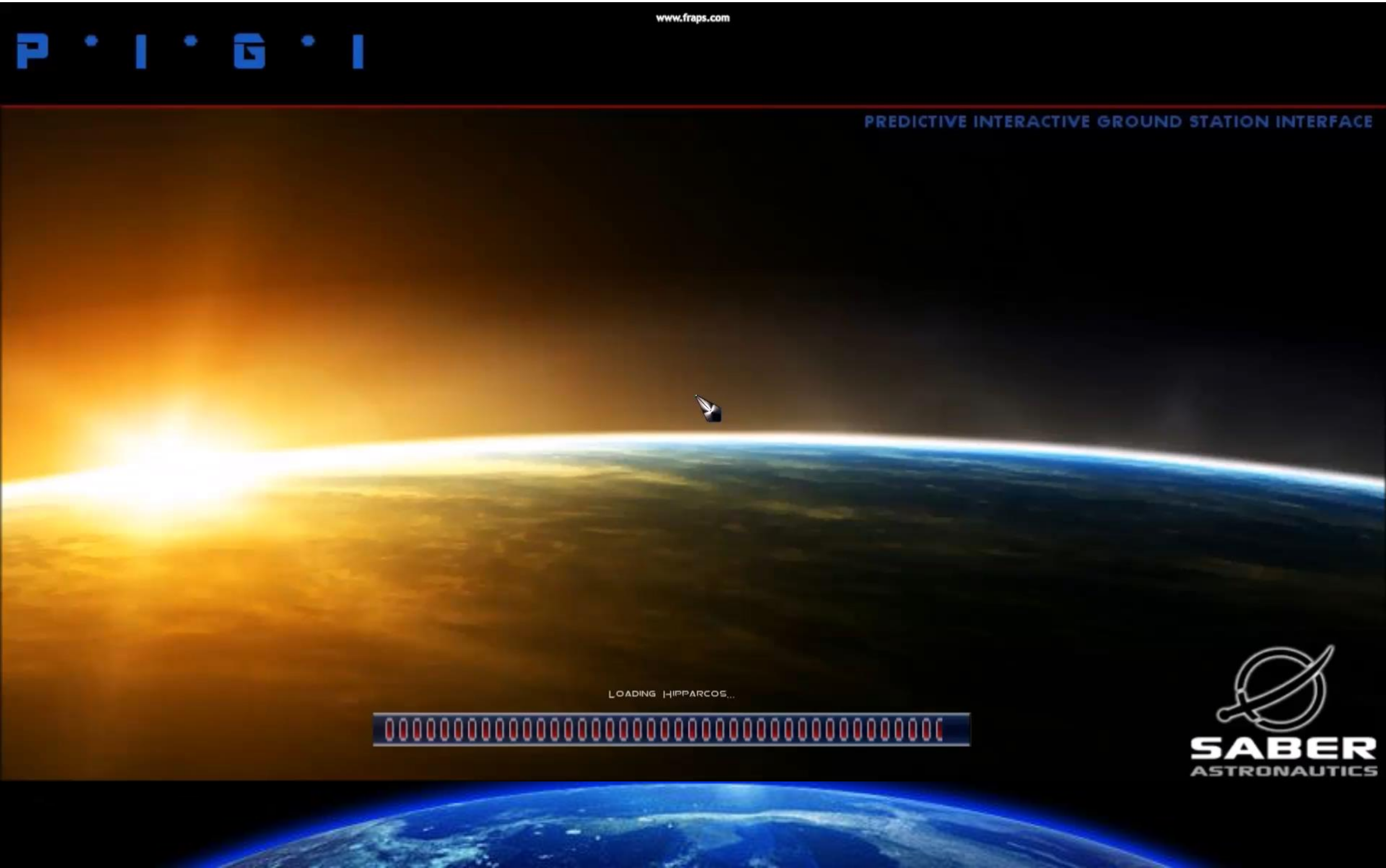
The process is like this:

"You have to knead your own bread to make a sandwich"

Satellite Design
Mission Planning
Dish commands
Satellite commands
Error tracking
Alert Systems
Databasing
Diagnostics
Ops software

A satellite mission

Solution - PIGI

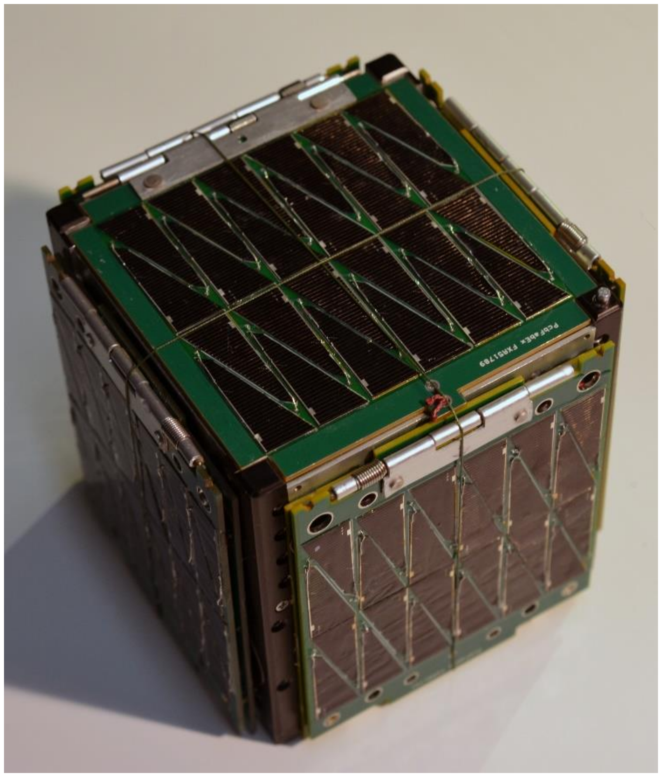


Now multiply that by 100

130 satellite constellation viewed in PIGI

Testimonial - SkyCube

"Level 2 Ops" from 2014-03-12 and 2014-07-09



Integrated software, graphics benefit

Direct observation and situational awareness

"You had twice as many connections as both active MC3 sites combined. "

SOUTHERN STARS

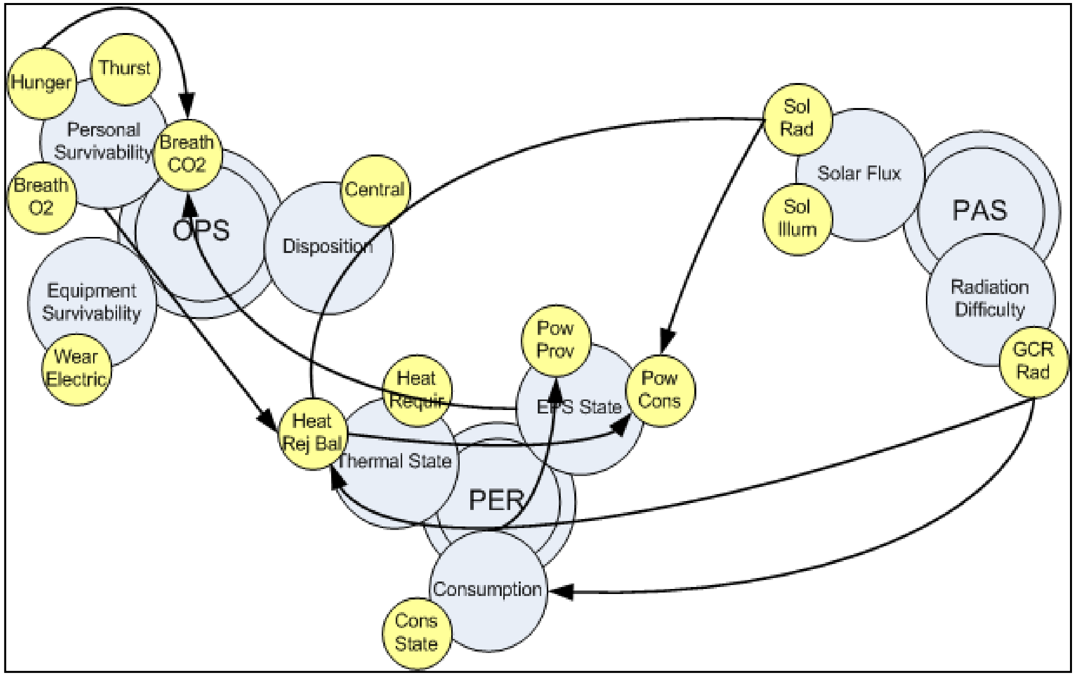
MC3 is the US Navy Small Satellite network

System Map

Model metric interactions

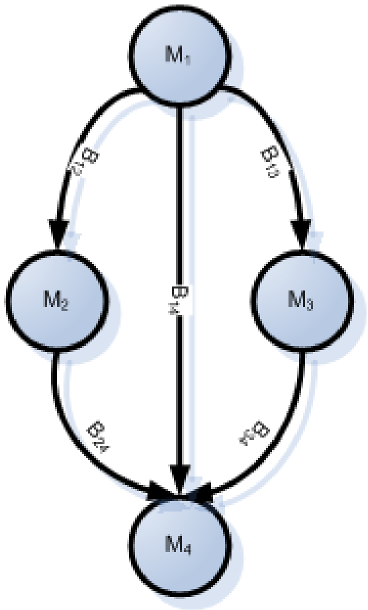
Options

- MLR
- Neural Networks
- Genetic Algorithms
- Bayesian Networks (DBN)



Bayesian Networks (BN)

- Represent each metric as a Gaussian
- If you know the connections, find parameters

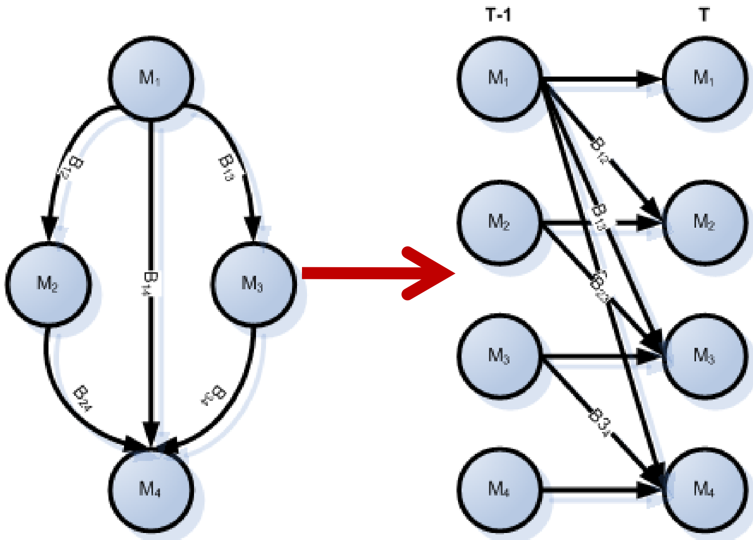


$$P(M_1,\ldots,M_n)=\prod_i P(M_i \mid Pa(M_i))$$

$$\theta_{ML}=\arg\max_\theta \log(Z_L \mid \theta)$$

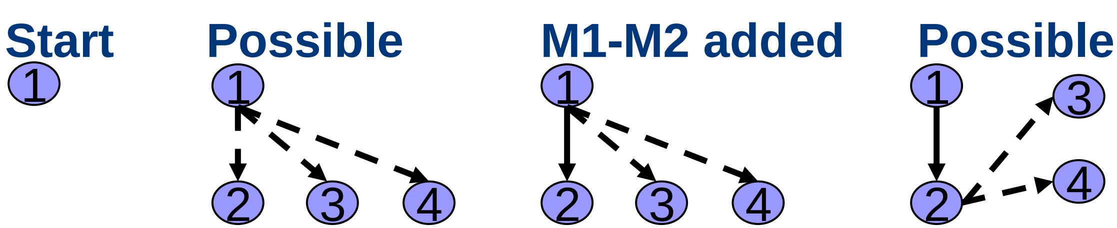
Dynamic Bayesian Networks

- 1st Order Markovian assumption

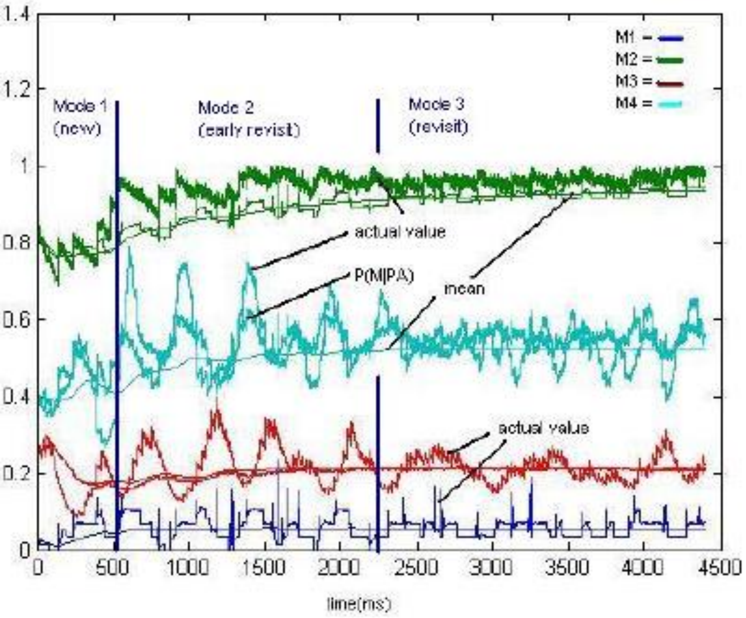


$$P(Z_{1:T}) = \prod_{t=1}^{T} \prod_{i=1}^{N} P(Z_t^i \mid Pa(Z_t^i))$$

- Unknown structure, full observability
- Search using a scoring function



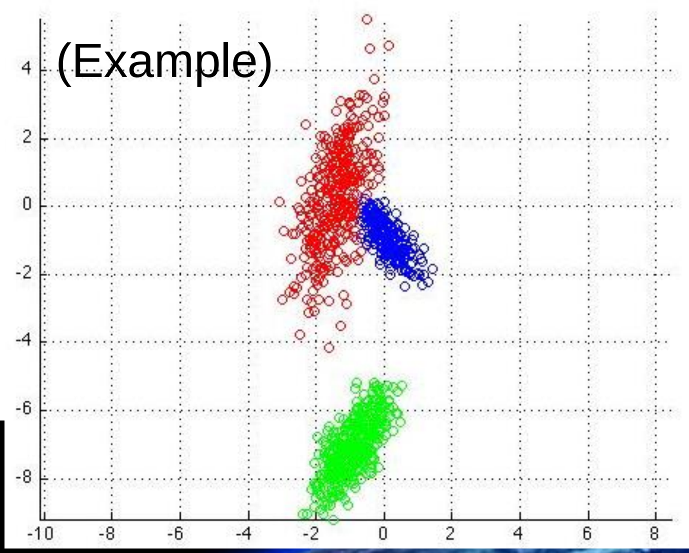
Switching States



Identify a change in mode

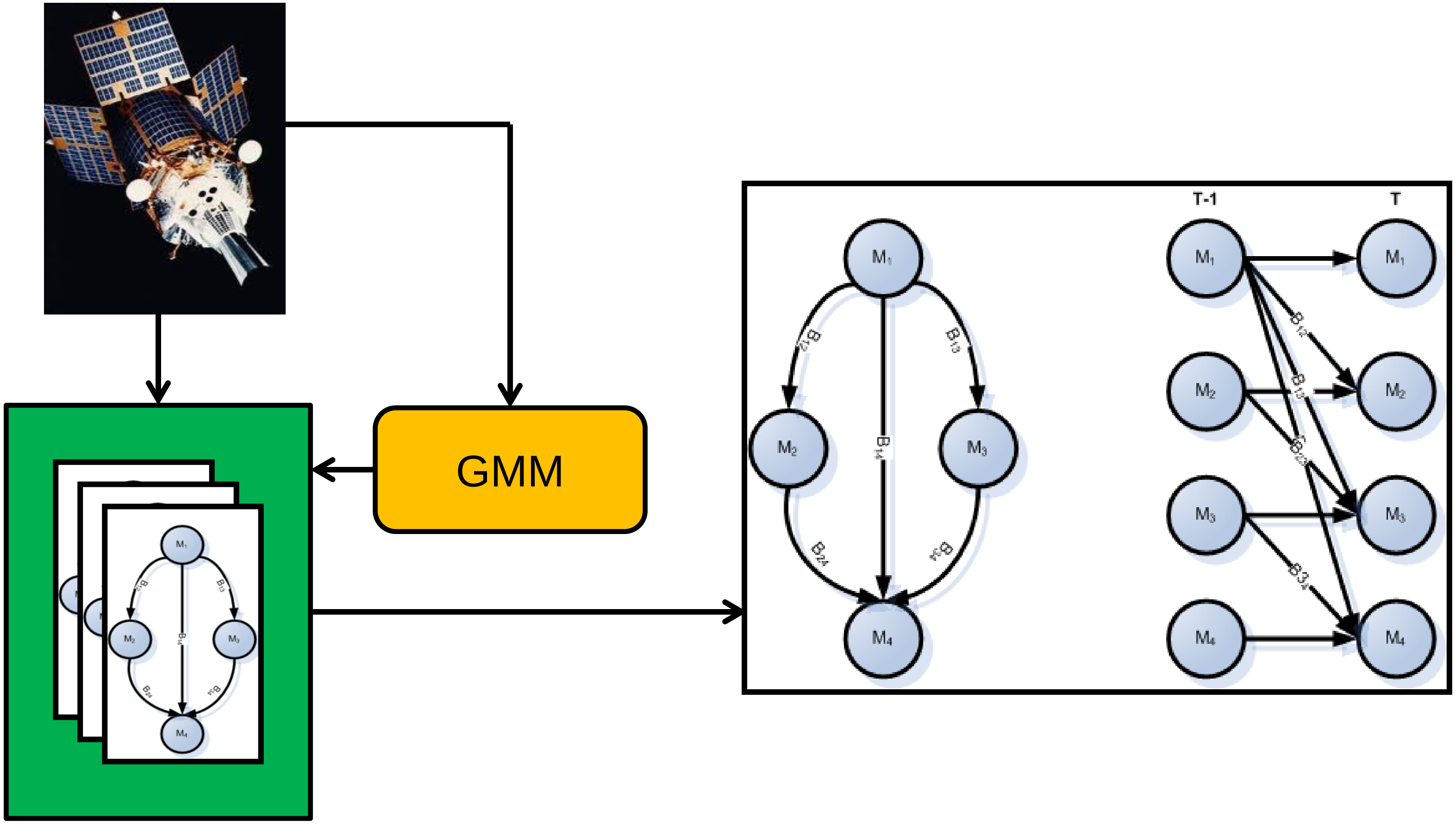
- Multiple (unknown) hidden states
- Single hidden state (EM)
- **GMM (EM)**

$$P(M_i \mid \mu_1 \ldots, \mu_k, s_1 \ldots s_k, \pi_1 \ldots \pi_k) = \sum_{j=1}^{k} \pi_j N(\mu_j, s_j^{-1})$$

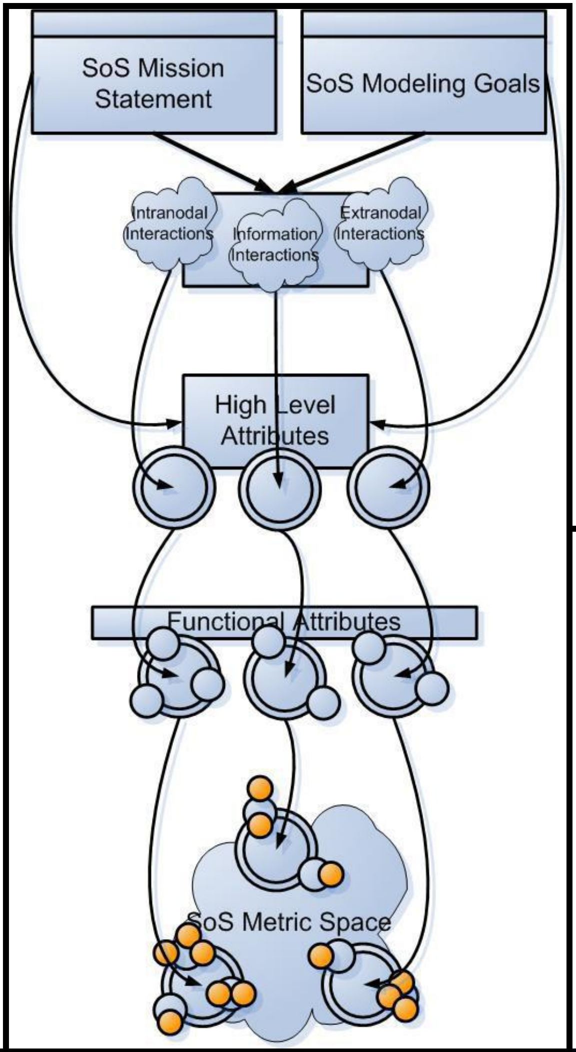


- Each mixture with its own DBN

At Run Time



NASA ACE Demo



NASA GSFC Support

NASA ACE H/W Telemetry

1200 Telemetry Items

SEC Data

120 words to model
22 Health Metrics
3 SPWX Metrics

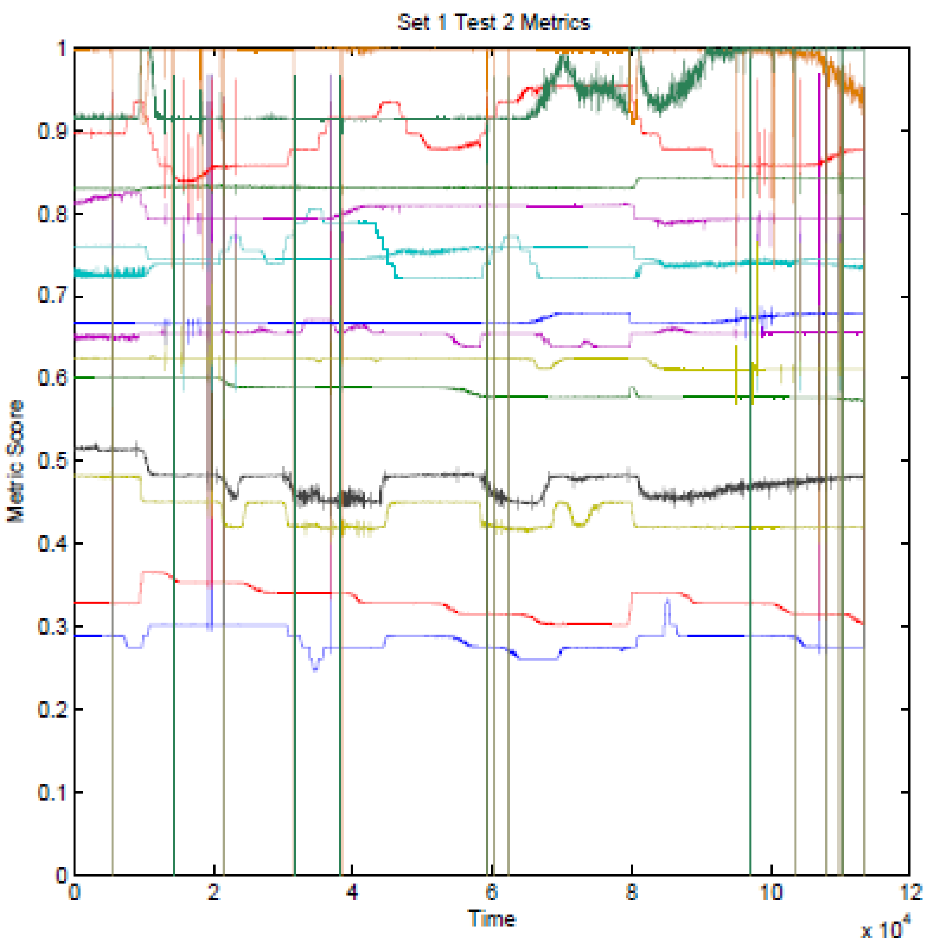
Experiments

Training Data – 2003 Solar Flare

Long Distance Nominal (2009)

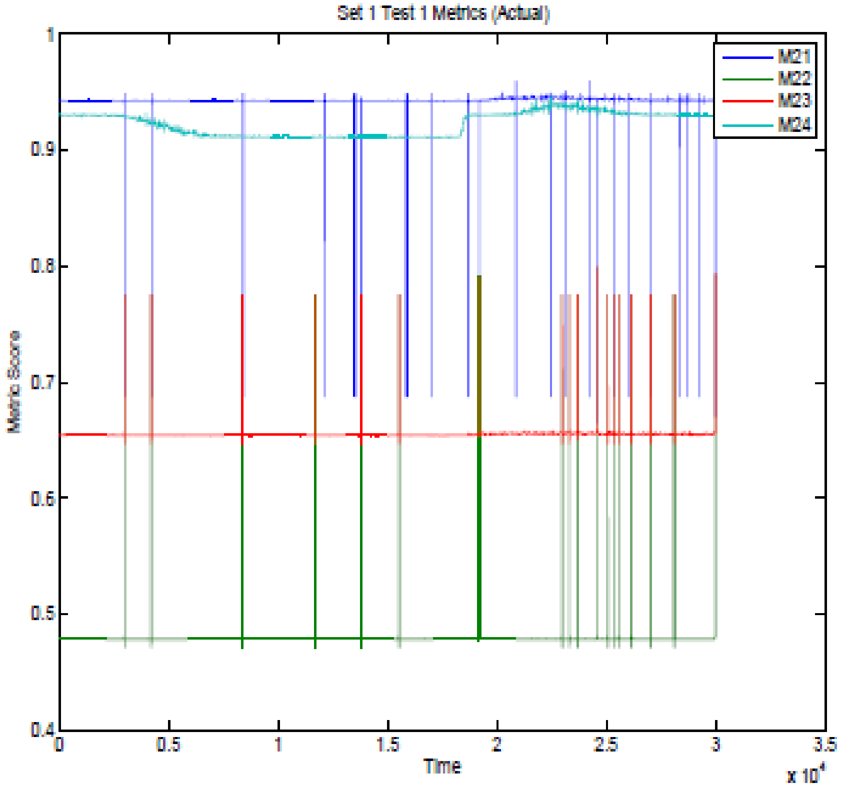
Long Distance Hazard (2011)

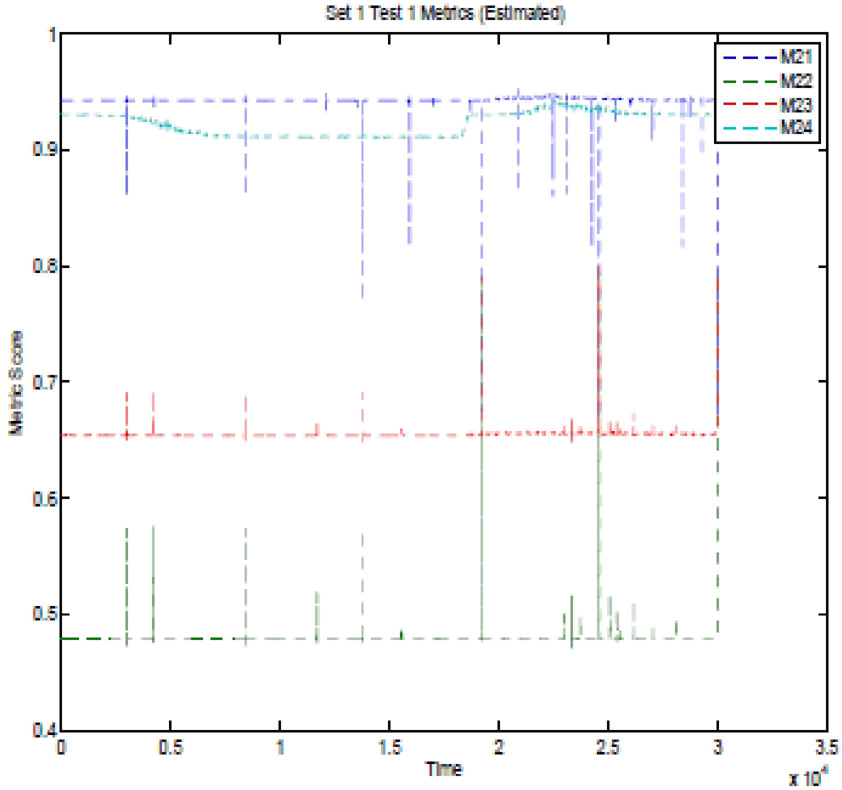
2-weeks of training data
8-years of experiment data



Results – Nominal tests 2009

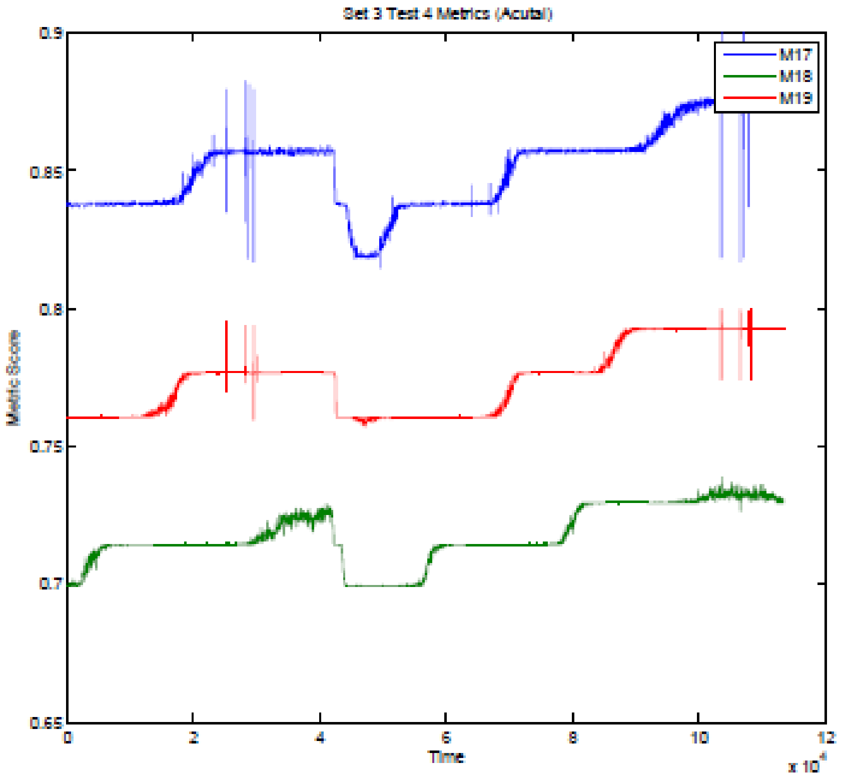
Signs of a general solution, but more work to do in SpWx metrics

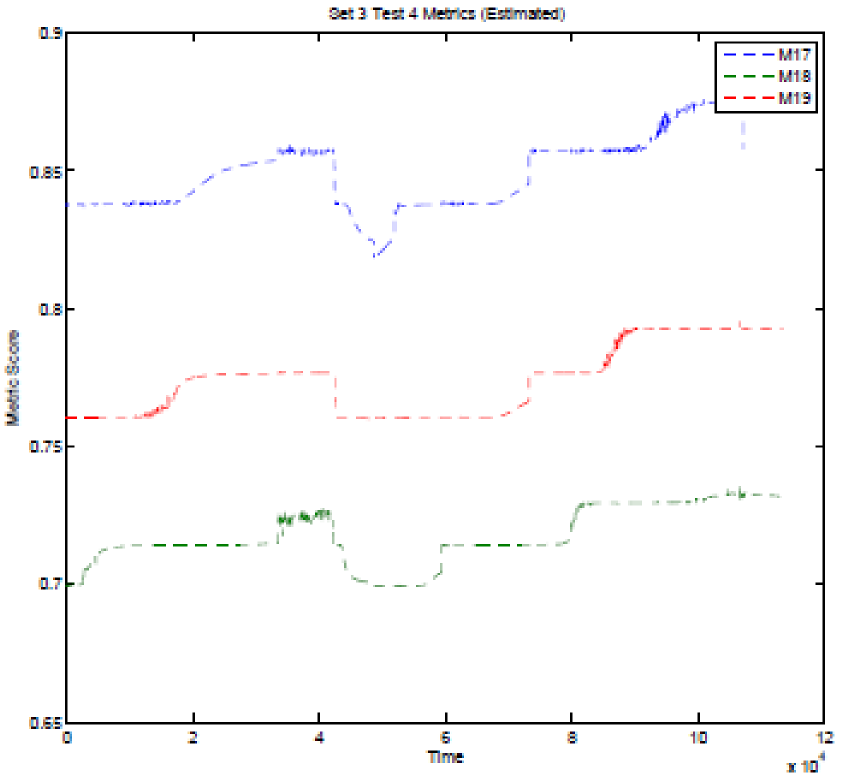




Results – Hazard tests 2011

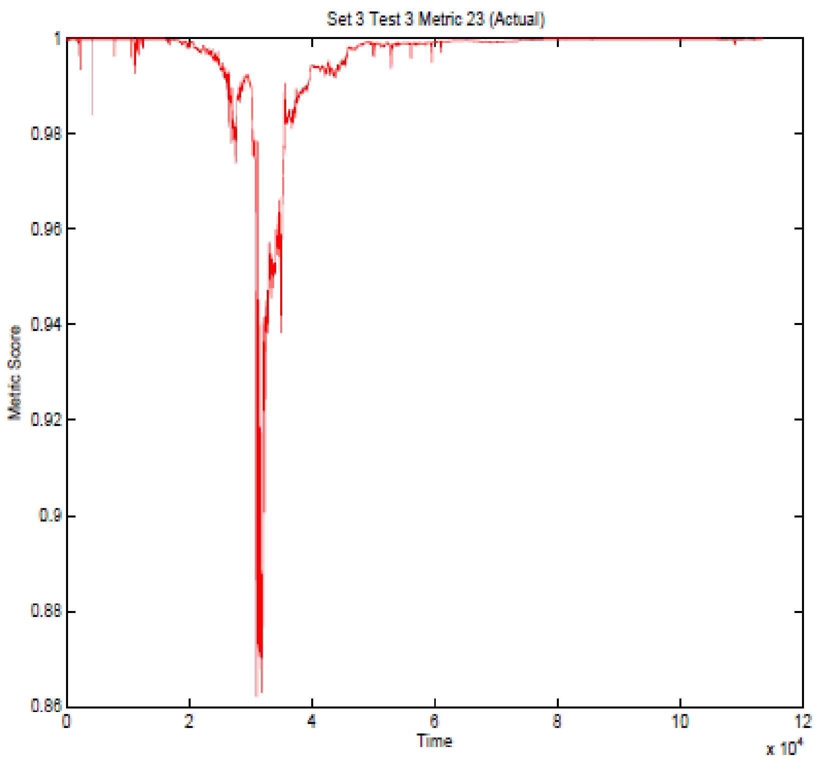
Metrics 17, 18, 19 – Payload Heat Capacity

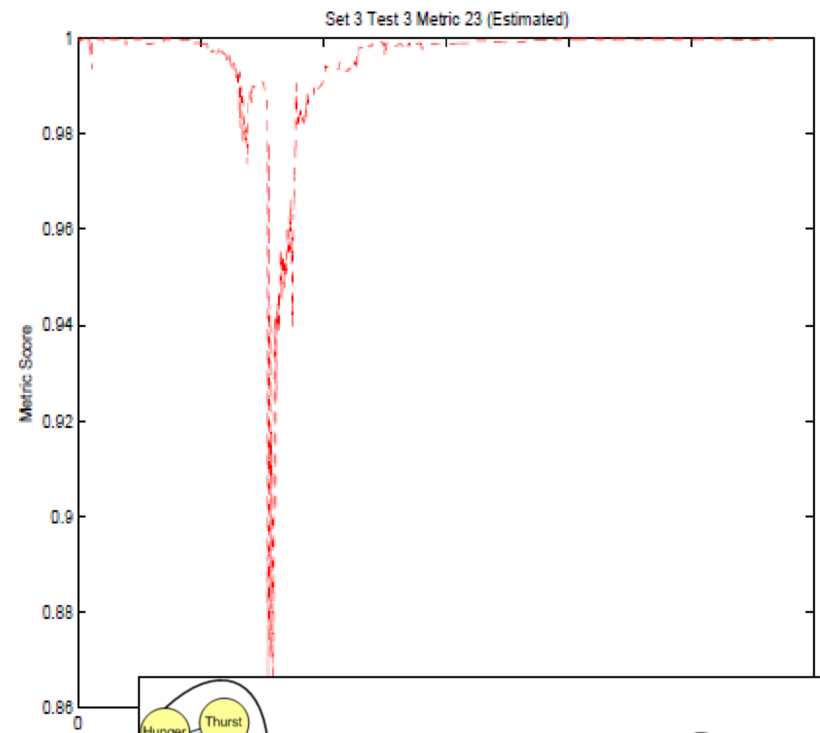




Results - Great

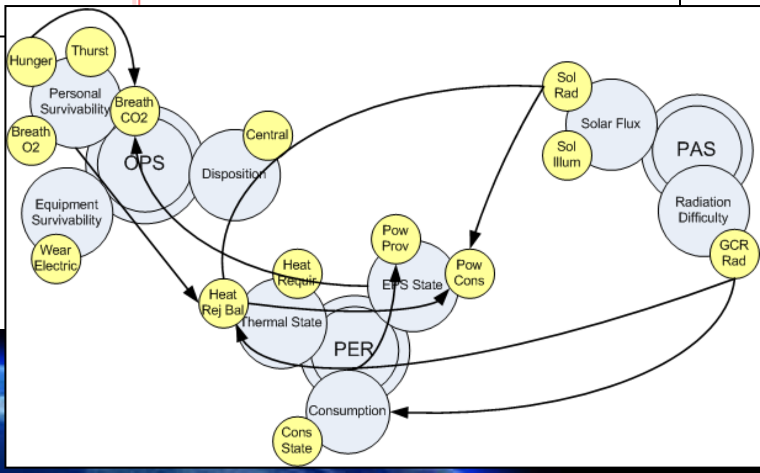
Metric 23 – Electron Hazard



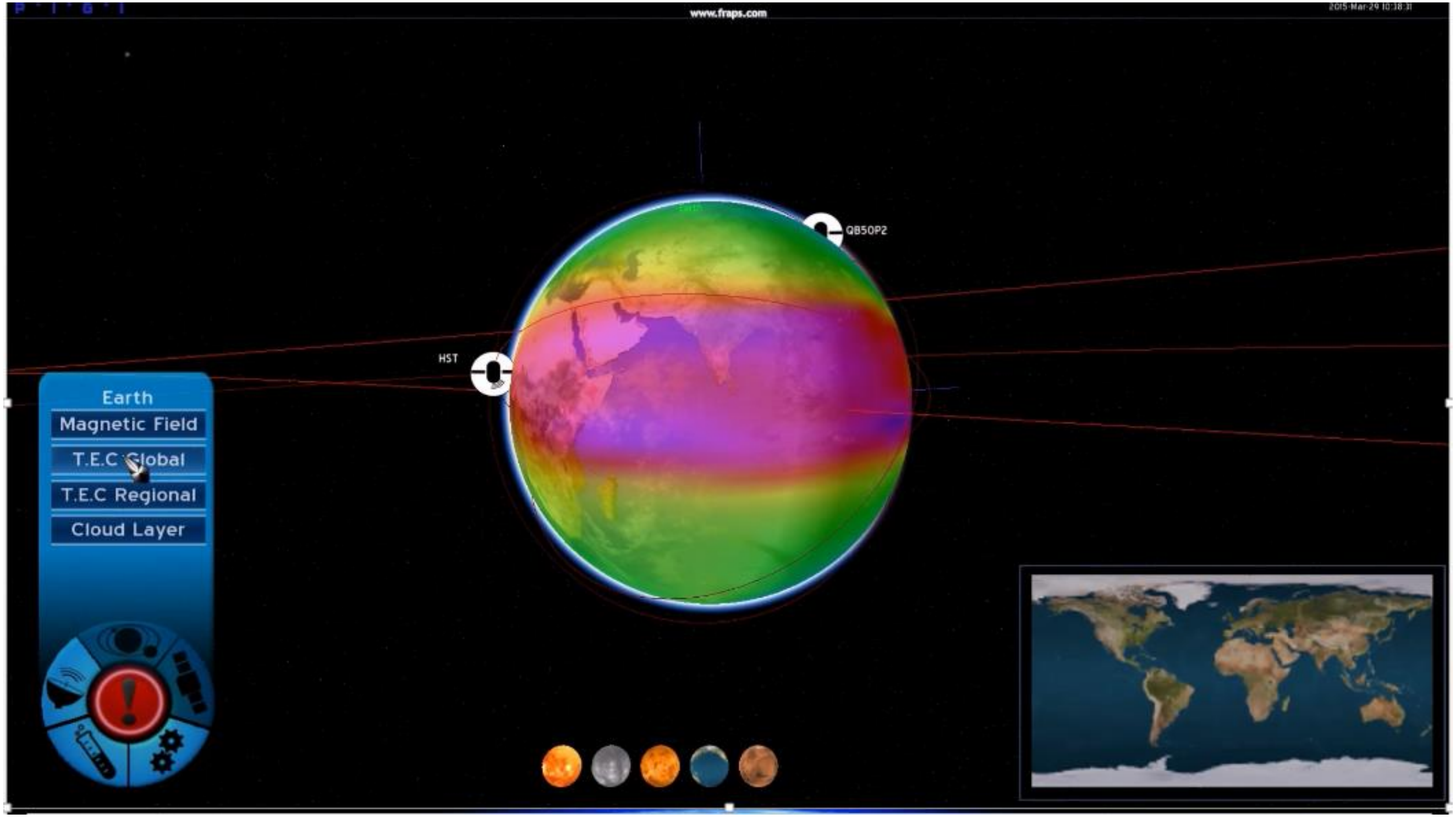


Time Invariant

Some aspects of a general solution



Real time services…



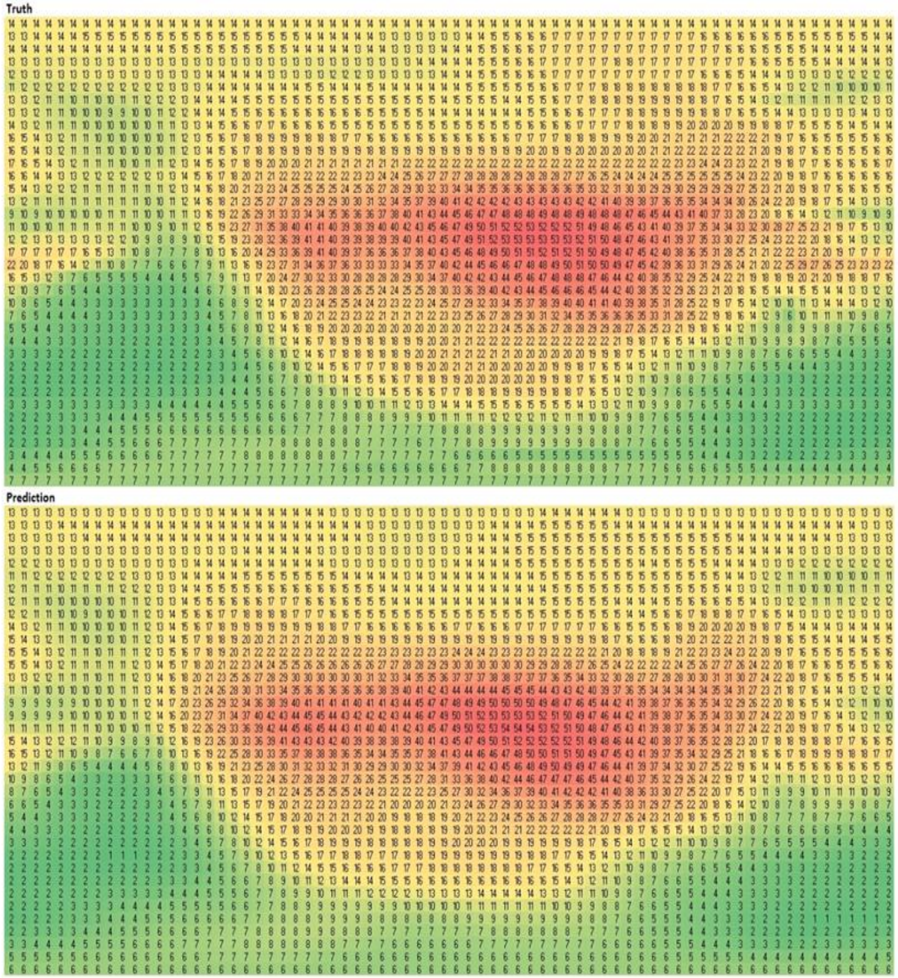
Space Wx prediction

Space Weather Prediction Service

- We can now predict Space Weather 1-3 hours ahead (92%-94%)

- This allows for spacecraft health prediction, preventative safing, safety operations, etc.

Services coming, stay tuned



Application: Morpheus

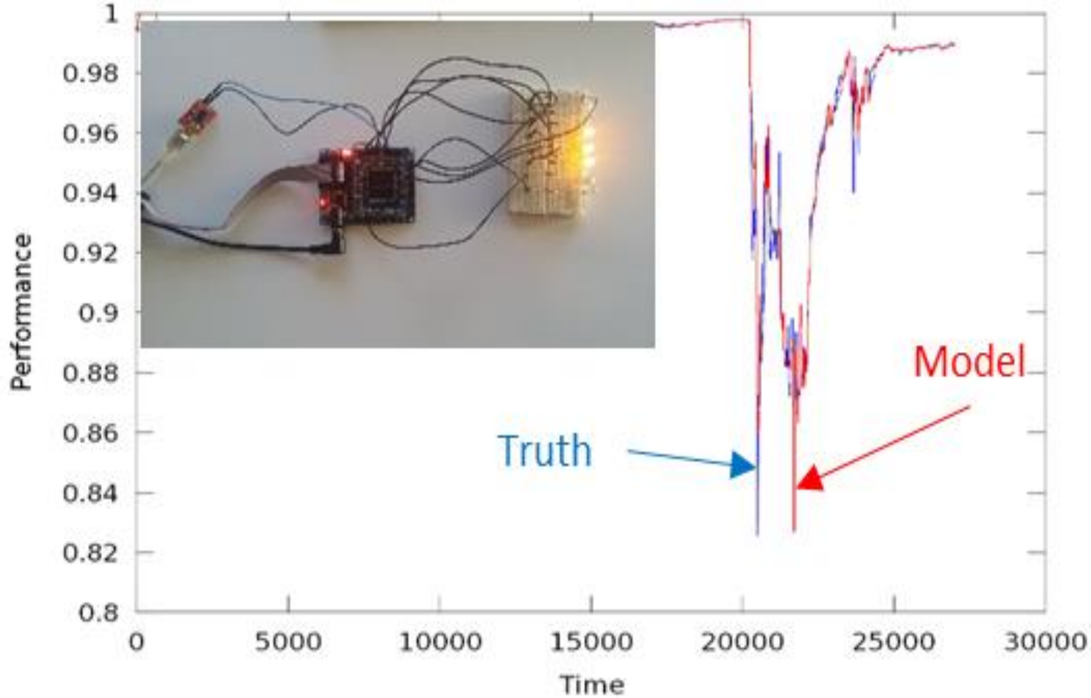
On-orbit, morphable avionics

NASA Phase-I SBIR

Reacts to heat, cold, radiation

Common interface to PIGI

CASIS Grant $200k



Put it in space, show value, then bundle like hell

Application: Telescopes

Research question: can System Maps improve telescope performance?

1. Systems of Systems Analysis

   What are the right metrics?

2. Prototyping on ground telescopes

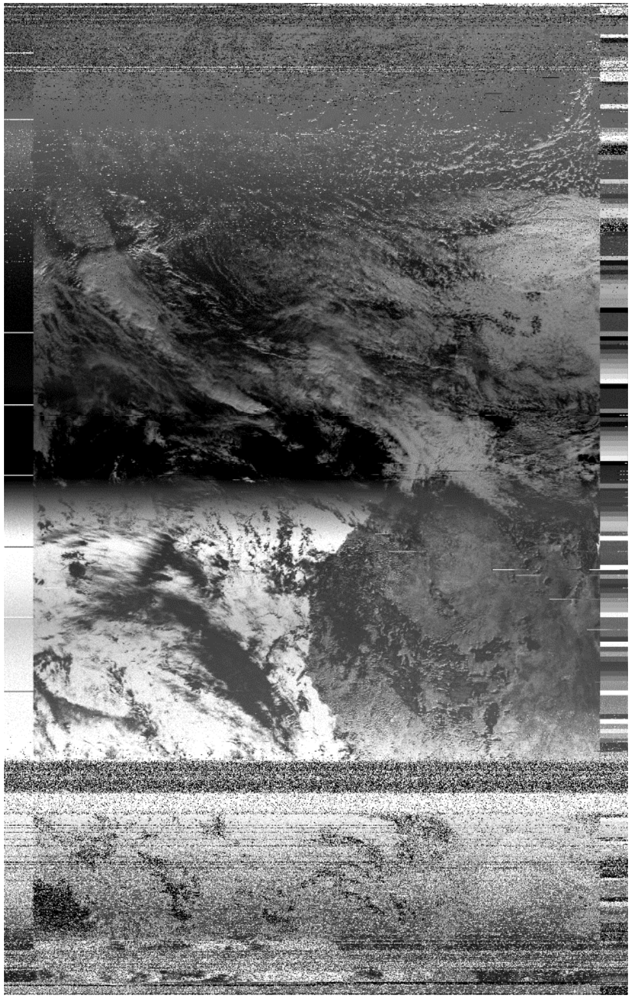
   Vibration
   Thermal
   Operational
   Atmospheric

3. Environ chamber testing

   Radiation
   Thermal cycling

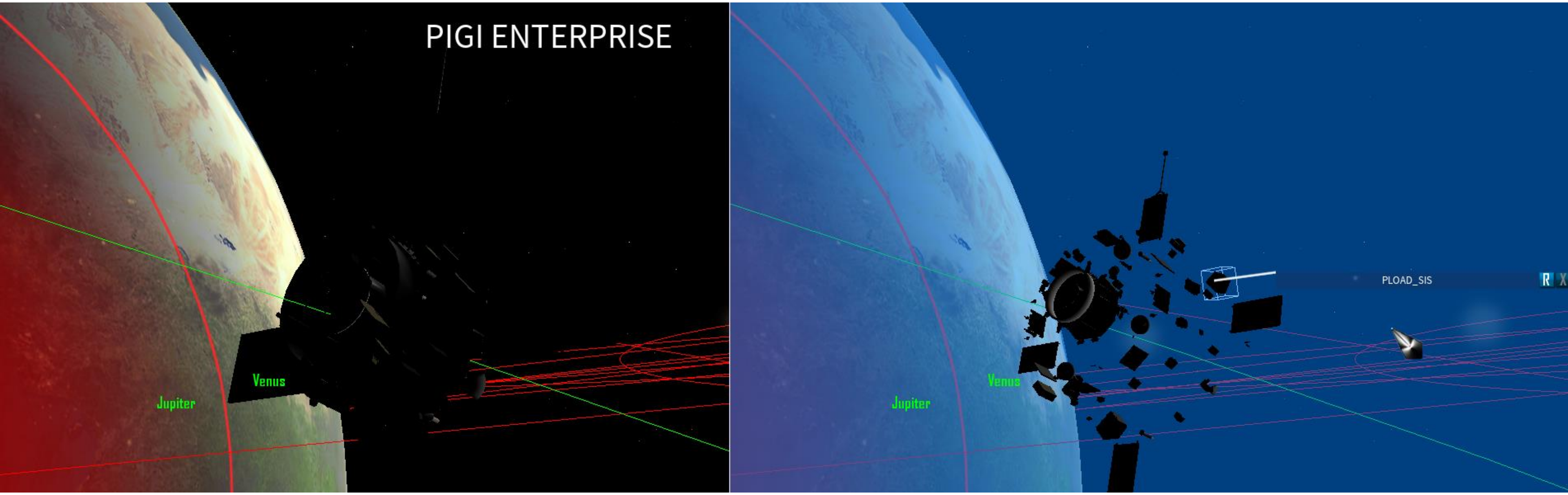
4. Flight

   Telemetric, Ionospheric



SABER ASTRONAUTICS

Conclusion



Achieved 97-99% accuracy in systems observation.

SEUs identification accuracy 71-85%

Integrated fleet services