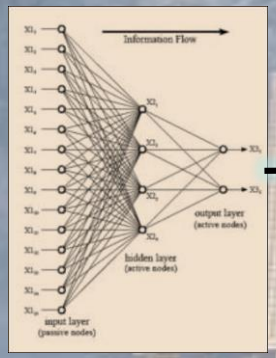
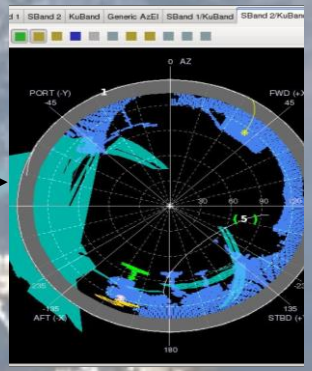
Flight Operations Directorate
Spaceflight Systems Division
and USAFA





Artificial Intelligence Integration for the ISS Antenna Management (IAM) Software

A collaboration project between NASA/FOD and the US Air Force Academy (USAFA)

Authors: CI23/D. Jackson, T. Quasny and USAFA/T. Giblin, D. Christman

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Overview

- Background/Description of the problem we are solving
- Overview of ISS Antenna Manager Capabilities
- Overview of the US Air Force Academy's Neural Network development
- Proposed integration approach
- Future developments
- Conclusion

Background/Description of the Problem We are Solving

- CRONUS has been accumulating experience with S-band and Ku-band comm availability for years.
  - But experience is disjointed – nine-hour shifts at a time, sometimes separated by 3-4 weeks of off-console work.
  - Hardened human experience on which to base future decisions requires one of two key ingredients:
    - Repetition of experience
    - An emotionally significant event or set of events
- The ISS Antenna Manager is on-duty 24X7X365 – if only it could remember its experience with the comm links.

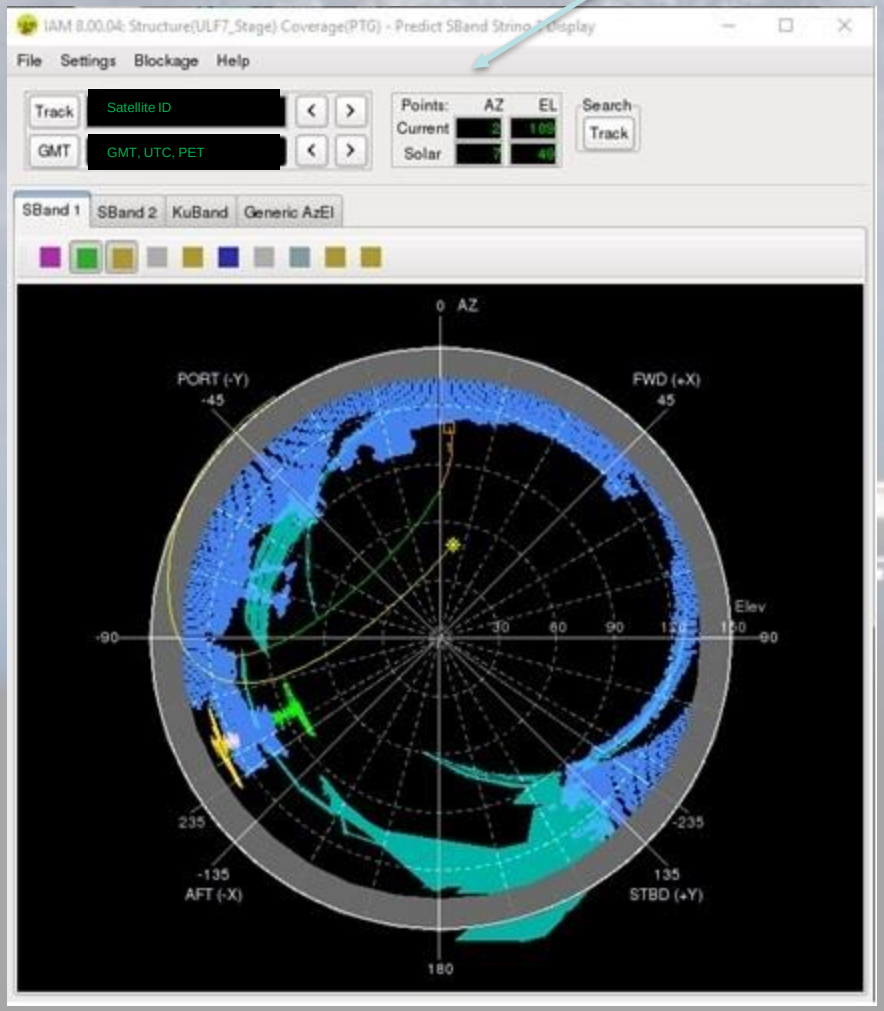
Background/Description of the Problem We are Solving (continued)

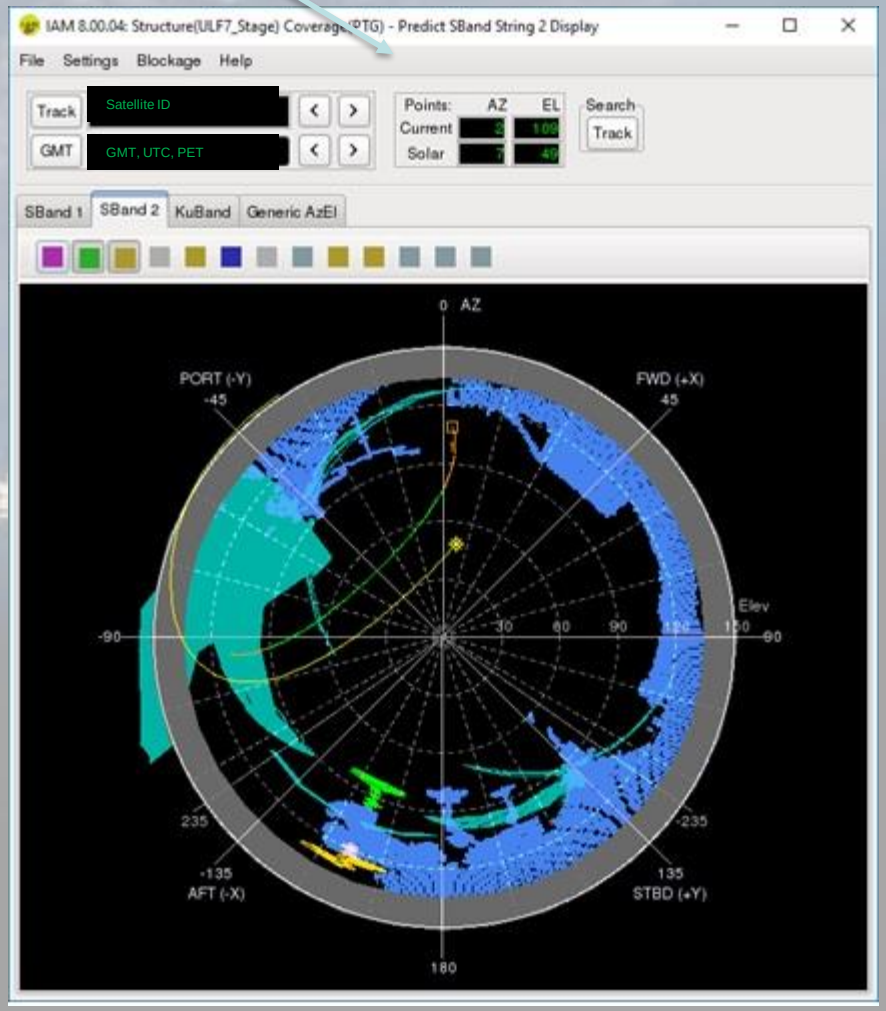
- Dr. Timothy Giblin from USAFA, who was once a crew trainer in FOD, was aware of this problem.
  - He proposed using USAFA student resources to develop a neural net aimed at assisting human judgement about comm availability.
  - Dr. Giblin worked with FOD personnel to develop an operations concept whereby artificial intelligence could make near-instantaneous inputs regarding communications availability.
- FOD personnel developed the bottom-line output for the neural network:

S-band: f(az, el, stbd-sarj, port-sarj, 2B, 4B, 2A, 4A, 1B, 3B, 1A, 3A, stbd-rad, port-rad) = digital AGC (signal level)

Overview of ISS Antenna Manager Capabilities

This is the S-band #1 and #2 view of the same prediction data.

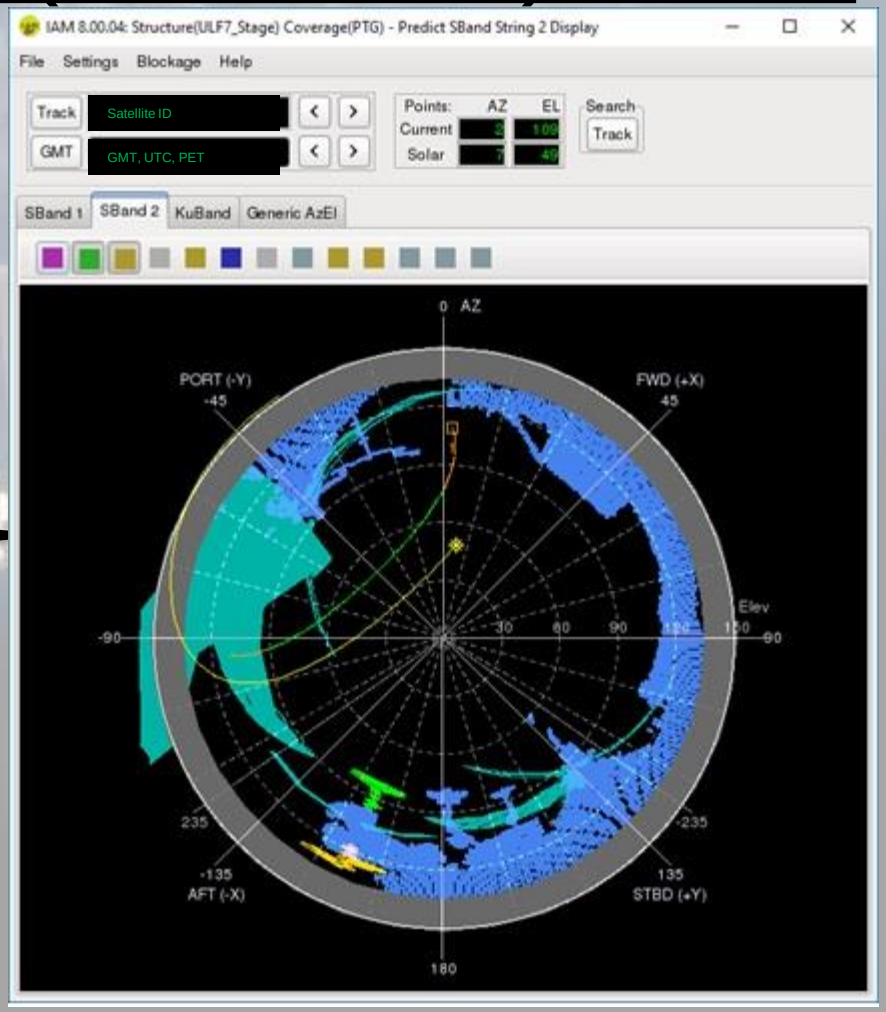




Overview of ISS Antenna Manager Capabilities (continued)

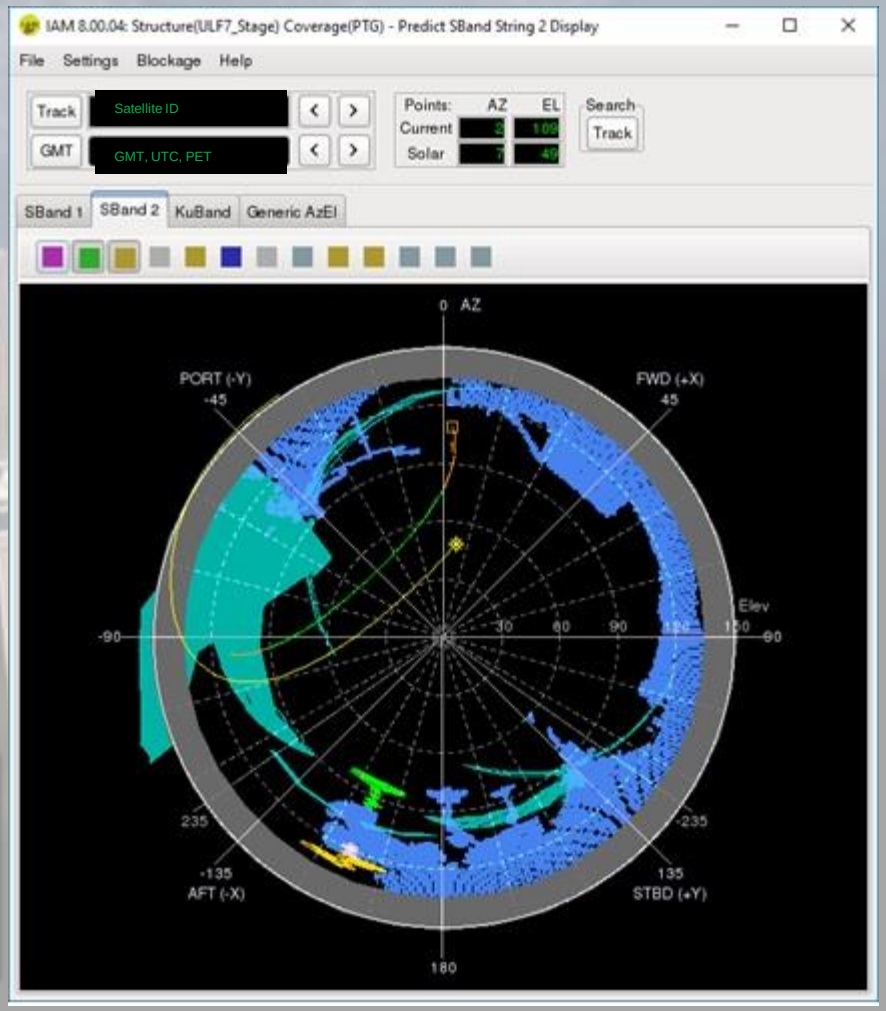
ISS State Vector/ Reboost plan and Attitude Timeline

- TDRS Track Predictions
- Solar Array Plan
- Sun Track Predictions
- TDRS Satellite Schedule



Overview of ISS Antenna Manager Capabilities (continued)

- TDRS Track Predictions exist in IAM as a chained set of data points (objects), each with a fixed set of characteristics:
  - Data Point: GMT, Azimuth, Elevation, Data Point Color, Pointer to Previous Data Point, Pointer to Next Data Point
    - Data Point: GMT, Azimuth, Elevation, Data Point Color, Pointer to Previous Data Point, Pointer to Next Data Point
      - Data Point: GMT, Azimuth, Elevation, Data Point Color, Pointer to Previous Data Point, Pointer to Next Data Point



Overview of the US Airforce Academy's Neural Network Development

Machine Learning Stand-Alone Prototype (MLSAP) – Operations (Phase I – where development is, now)

- Machine learning software tool accepts ISS-TDRS Predict Data, makes AOS-LOS prediction, based on the algorithm's predicted digital AGC (S-band). (currently binary: 1 = AOS, 0 = LOS, "ratty" comm feature for future implementation)
- MLSAP is currently a separate computer software configuration item from IAM (integration is a future plan).
- Validation & Testing Phase: initial machine learning tool will run on MCC platform in parallel with IAM on flight controller console
- Performance Evaluation: ISS flight controllers cross-reference and log legacy predictions with MLSAP visual AOS/LOS status

Overview of the US Airforce Academy's Neural Network Development (continued)

Machine Learning Stand-Alone Prototype (MLSAP) – Function

- Machine Learning Algorithm Selection involved a trade study: Neural Network (NN) was the chosen approach
- NN Prototype build/platform: Python 3.5
- Neural Network: a set of interconnected nodes that mimics the human brain. The NN learns instances, does not predict models or "why" an LOS instance occurs, but only that it does or does not, based on historical performance.

Overview of the US Airforce Academy's Neural Network Development (continued)

Machine Learning Stand-Alone Prototype (MLSAP) – Function (continued)

- NN Prototype Architecture: currently 3-layer neural network

Input Layer:

17 input attributes ISS Performance Data

(1) Hidden Layer:

8 nodes (to be increased to 34 in future iteration)

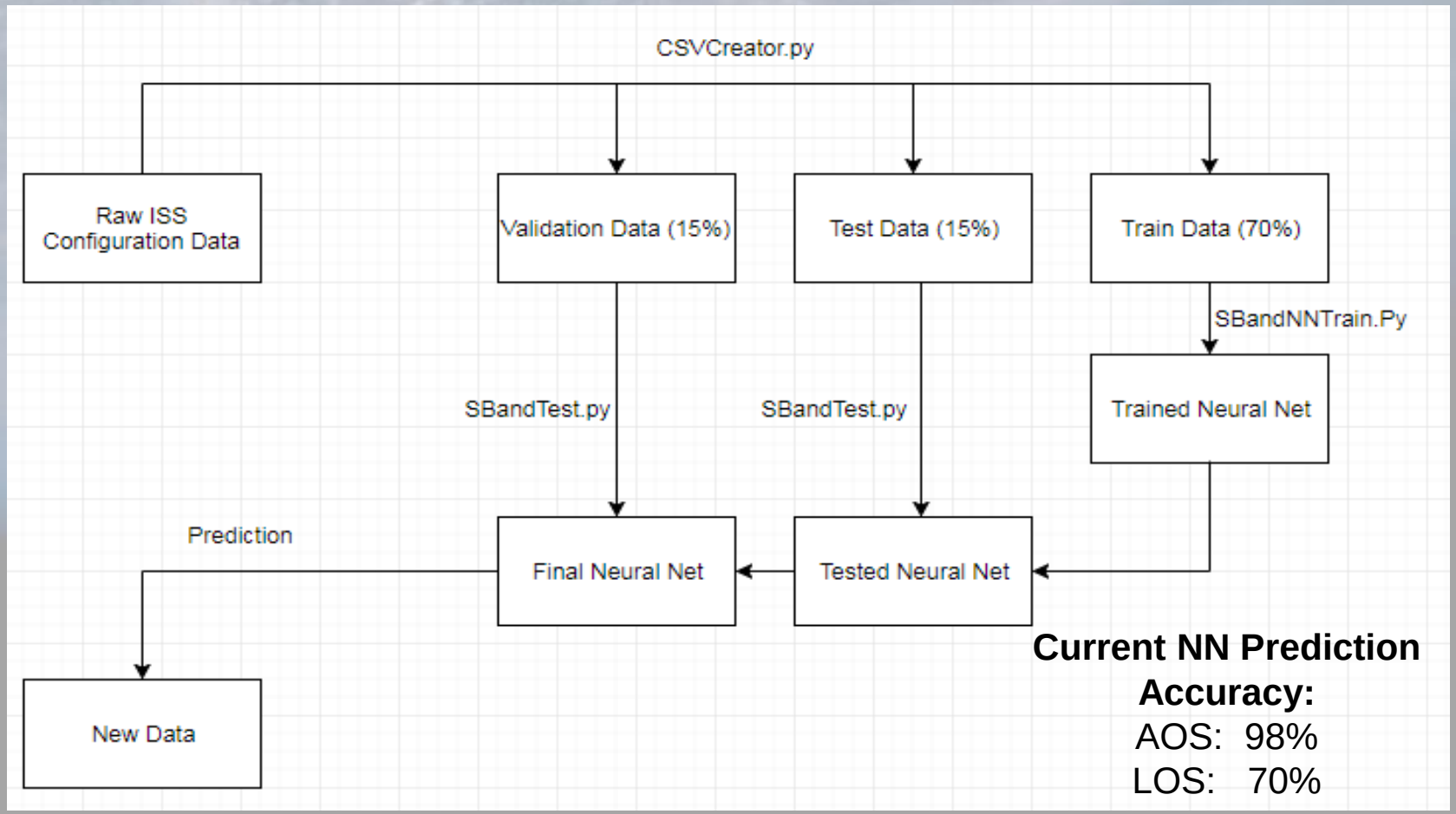
Output Layer:

2 outputs

[The discontinuous nature of the ISS Performance Data will demand the addition of an additional (2nd) hidden layer]

Overview of the US Airforce Academy's Neural Network Development (continued)

Initial Approach for ISS Performance Data NN Processing



Proposed Integration Approach

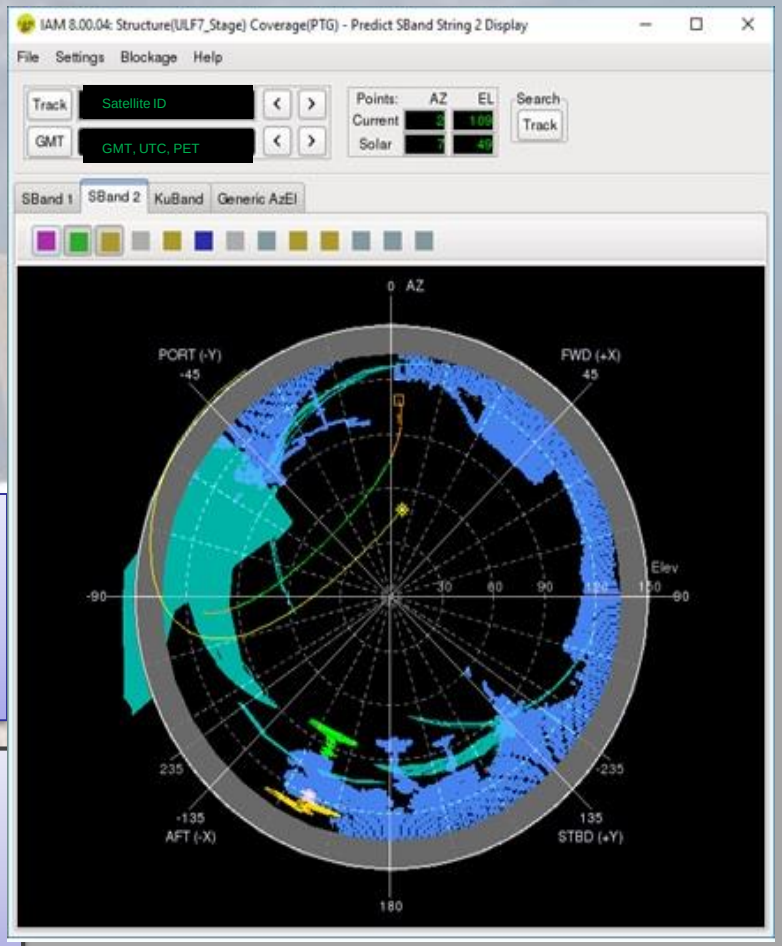
Machine Learning Component of IAM – Integration (Phase II & III)

- Update Neural Network (NN): additional (hidden) layer to improve prediction accuracy.
- "Close the loop" by advancing the NN development to use realtime data to assess how accurately it predicted comm availability and adjust accordingly.
- Single NN for each antenna string (currently NN only for S-band #1)-- develop NN for the two Ku-band antennas
- Integrate tool into existing c-based IAM code with Active Machine Learning (cyclic update of NN based on realtime/continual ISS Performance Data)

Future Development (continued)

- TDRS Track Predictions exist in IAM as a chained set of data points (objects), each with a fixed set of characteristics:
  - Data Point: GMT, Azimuth, Elevation, Data Point Color, Pointer to Previous Data Point, Pointer to Next Data Point
    - Data Point: GMT, Azimuth, Elevation, Data Point Color, Pointer to Previous Data Point, Pointer to Next Data Point

The resultant NN from this research will make “ratty” or “bad” comm calls by applying a color to each data point in the TDRS track.



Conclusion

- This project represents an ideal opportunity to develop paradigms about the application of artificial intelligence into future spacecraft operations.
- Advanced data processing/interpretation capabilities could be transferred on-board future spacecraft in disciplines involving around-the-clock operations.
- NASA/FOD and the USAFA should continue development of this project to garner maximum benefits from this research.

Backup Charts

- CI2/Dan Jackson is a Senior Communications Fellow with KBRWyle who developed the original ISS Antenna Management operations concept, requirements and software for the ISS sun-tracking components.
- CI2/Todd Quasny is a Command, Control and Communications specialist/flight controller who also possesses Instructor accreditation. He is the lead consultant on this project with extensive education and experience in integration of artificial intelligence systems.
- USAFA/Dr. Tim Giblin is the USAFA's Program Director, Quantitative Reasoning Center & Physics Professor. FOD crew trainer at NASA/JSC (2008-2013), originally certified the first Linux version of IAM for CRONUS Operations.
- Del Christman, Program Director of Machine Autonomy, Reasoning, Vision and Learning Research. USAFA Center for Cyberspace Research

Backup Charts

(continued)

- We extend our greatest appreciation to the cadets of the US Air Force Academy who developed the first-ever neural network in support of International Space Station Antenna Management:
  - Jordan Stiles, B.S. Computer Science
  - Ben Gautier, B.S. Computer Science
  - Sam Lohnes, B.S. Computer Science
  - Cedric Hines, B.S. Computer Science
  - John Reynolds, B.S. Computer Science
  - Gearick Watt, B.S. Systems Engineering – Human Factors