Prognostics As A Service (PaaS) Advisory Working Group

Initial Meeting
January, 2018
PaaS Team

Chris Teubert (NASA ARC): Project PI, Group Lead Diagnostics and Prognostics

Nelson Brown & Otto Schnarr (NASA AFRC): Autonomy, Large UAS/UAM

Patrick Quach (NASA LaRC): Small UAS

Mark Muha (NASA GRC): Security Expert

Robert Kerczewski (NASA GRC): Communications Expert

Jason Watkins (NASA ARC, SGT Inc.): Software Engineer
Meeting objectives:

1. Establish a common understanding of the PaaS project and concept
2. Establish a common understanding of the purpose of the working group
3. Introduce PaaS team members & WG members
4. Provide initial feedback and guidance to the PaaS Team
Prognostics

Prognostics uses sensor data to provide real-time assessment of

1. **Current Health State**
2. **Future Health States**
3. **Future Performance**
4. **Failure Prediction**

For systems, vehicles, airspaces

\[ f_i(t) = f_p(p_i(t), u_i(t)) \]
\[ f_b(t) = f_p(p_b(t), u_b(t)) \]

\[ EOL(t_P) \triangleq \inf\{t \in \mathbb{R} : t \geq t_P \land T_{EOL}(x(t), \theta(t)) = 1\} \]
Prognostics - Utility

- Pilots
- Remote Operators
- Air Traffic Control
- UAS Traffic Management (UTM)
- Airline Dispatch
- Autonomy
- Maintainers
Prognostics - Utility

- Provide health information for components, vehicles, airspace

- Pilots
- Remote Operators
- Air Traffic Control
- UAS Traffic Management (UTM)
- Airline Dispatch

- Autonomy
- Maintainers

- Reduced Risk of failure of critical systems
- Reduced System Delays
Prognostics- Utility

Impact: Enabling Robust Autonomous Systems

Autonomous Systems that:
1. **Monitor** health in-flight
2. **Predict** failures in-flight
3. **Understand** how performance degrades
4. **Autonomously** make decisions based on this
Prognostics - Utility

- Pilots
- Remote Operators
- Air Traffic Control
- UAS Traffic Management (UTM)
- Airline Dispatch
- Autonomy

Maintainers

Reduced Maintenance Costs
PaaS Users

- Pilots
- Air Traffic Control
- Maintainers
- Remote Operators
- UAS Traffic Management (UTM)
- Airline Dispatch

All could potentially be human or autonomous
Prognostics As-A-Service (PaaS)

Identify, explore, and develop solutions to mitigate the technical barriers and design decision space for performing prognostics remotely, as-a-service at a large scale
## Challenges

<table>
<thead>
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<th>Can a single PaaS system support the wide variety of aircraft classes and configurations?</th>
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Prognostics As-A-Service Prototype

Sources: UAS

Sinks: GUI, Report Generator, Autonomy, etc.

Service Request, Sensor Data

Results

PaaS API (REST)

GUI

Prognostics Instance

Prognostics Instance

Prognostics Instance

PaaS System
April 2017

**Project Formation**
Identify the challenges of the PaaS architecture, formulate a project plan

April 2018

**Prototype Development**
Design, develop, and test prototype PaaS System

October 2018

**CASTInG Gate & Further Development**
Present PaaS at CASTInG Gate, pitch for integration with other projects.
Meanwhile continue to mature the PaaS prototype

April 2020

**Feasibility Study**
Study to establish the feasibility of overcoming the 6 primary challenges of the PaaS Architecture, and identify solutions to these

**PaaS Working Group**

**Release, integrate into NASA projects**
To advise in the identification and investigation of feasibility challenges for the PaaS Architecture, and on how feasibility can be established in a manner meaningful to industry and academia.
Working Group Membership

24 individuals from across government, industry, and academia

- Academia
- Urban Air Mobility
- Government
- Unmanned Aircraft Systems (UAS)
- Intelligent Data Providers
Discussion

Please say name and company/organization before speaking
Questions

- Why are you interested in prognostics as-a-service?
- What challenges do you see for this architecture?
- What would you need to feel that this technology is mature enough to use?
### Challenges

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Backup Slides
Potential Strengths/Weaknesses of PaaS Architecture

**Strengths**
- Computational constraints
- Access to external data
- Ease of integration, maintenance
- Ease of extension
- Size, Weight, and Power (SWaP)
- Efficiency of resource sharing
- Data collection/learning

**Weaknesses**
- Communication security concerns
- Communication stability/availability
- Latency/bandwidth constraints
GSAP

- Live Sensor Data
- Future Loading
- State Estimation
- Prognostics Results

The Outside World

ProgManager

Communicators

Data

Prognosers

Support Library
Model-Based Prognoser

Observer Step
- Sensor Data
- Loading Data
  - Observer Algorithm
  - System Model

Estimated Health State
Future Loading (Flight Plan)

Prediction Step
- Predictor Algorithm
  - System Model

Remaining Useful Life
Prototype Shortcomings

- REST is not the best format for an API for streaming sensor data/results- Consider other architectures
Chosen Architecture

Architecture
Cloud Enhanced Prognostics

Utilizing Cloud Resources
As-A-Service

Reasoning for Architecture Choice
- Computational constraints
- Utilizing external data
- Ease of integration, Maintenance
- Ability to integrate new features
- Improve with use
- Size, Weight, and Power (SWaP)
- Resource Sharing (Efficiency)

Take-away
A cloud-enhanced architecture can provide prognostics technologies to all aircraft and includes additional efficiency, capability, and performance advantages
Demonstrating Feasibility

Test the ability to address the six challenges with a proof of feasibility system, for small and large UAS (UAM representative vehicles), with different end users

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Testing Communications and Environmental Complexity

Communication:
- Communications Constraints (e.g. Bandwidth, Latency)

Environmental Complexity:
- Different environmental factors

Experts from both of these will be involved with developing requirements, designing experiments, and final feasibility assessment.
Testing Security

A - Sensor Security
- Vehicle Sensor to Vehicle Aggregator Interface
- Aggregator/Agent Security

B: Broadcast Medium Security

C: Antenna Security

D: Inter Prognostics Service Utility Information processing (cloud)

E: Service Level Agreements (QoS, Security Levels Provided) between external receiver owners and prognostication utility.

F: eUtility (Cloud) resource access Cloud to data consumers

Protect Confidentiality, Integrity, and Availability (CIA Triad)

Security expert on team
Hardware-In-The-Loop FlightDeck

Leveraged for PaaS HITL
- Consists of cockpit with flight controls, autopilot, radio
- Connected to prognostics virtual lab
- Can display prognostics results on GUI on left screen

Operation Station
- Connected to prognostics virtual lab
- Controls experiment, can operate as ATC or Dispatch
Prognostics Virtual Lab

- Set of tools for distributed prognostics experiments
- LVC Gateway used to share network messages for aircraft, and systems
- Connect HITL Elements, Virtual and Real aircraft, prognostics algorithms, GUIs, etc.
Deliverables

- Feasibility Assessment Document
- Protocol Recommendations
- Publicly Released Proof of Concept PaaS system
- Publicly Released Data
Approach

1. Requirements
2. Design and build proof-of-concept
3. Test Early, Test Often
4. Disseminate data, software, results
5. Transition

Deliverables

- Publicly Released Proof of Concept PaaS system
- Protocol Recommendations
- Journal/Conference Publications
- Publicly Released Data
Fitting all this together
SHARP Laboratory

- Laboratory for the development of testbeds and test systems
- Verification and validation of mathematical models
- Electric propulsion system testbed
- Flight simulation system and flight deck
- Power supplies, oscilloscopes, and data acquisition systems.
Factors in Choosing PaaS Targets

These factors should be considered when choosing systems to target for PaaS:

1. Criticality of system
2. Difficulty
3. Likelihood of failure
4. Ability to detect health state and predict failure
5. Utility- ability to take action based on the results of prognostics
6. Commonality- How often is this system used on aircraft
Context Diagram

- Configuration
- Identification
- Sensor Data
- External Data
- PaaS
- Prognostics Results