Actuator Systems Prognostics
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Introduction
- Actuators are mechanical, pneumatic, hydraulic, electrical, or hybrid devices that perform a mechanical motion in response to an input signal
- Actuator failures in complex systems, such as aircraft or spacecraft, can lead to catastrophic consequences

Select Case Studies
- Scaled Composites SpaceShipOne
- Alaska Airlines MD-80 flight 261

Overview
Potential Fault Modes
- Faults in electrical connections 5%
- Mechanical faults 30%
- Faults in windings 5%
- Faults in bearings 30%
- Thermal faults 30%

Challenges
- Non-invasive prognostic methods requirement
- Limited built-in sensor suites
- Restricted on-board computational resources

Objectives
- Detect and classify incipient faults
- Estimate Remaining Useful Life (RUL) given a degraded mode
- Provide an accurate picture of EMA component health
- Generate real-time actions or recommendations for extension of RUL

Methodology
Test Article
- Linear electro-mechanical actuators (EMA) selected
- Moog MaxForce is a ballscrew, direct-drive design

Data Collection
- Initial data collected at Moog Inc
- EMA test stand constructed at NASA Ames
- Capabilities include: 5 metric ton load capacity, accommodation of test actuators of various sizes and configurations, and custom motion and load profiles

Sensor Suite
- Vibration, load, and temperatures sensors
- High-precision position sensors
- Current sensors

Initial Set of Fault Modes
Mechanical faults
- Ball screw return channel jam
- Lubricant deterioration
- Backlash

Motor faults
- Air gap eccentricity
- Insulation and conductor degradation

Diagnostic System Development
- A neural network based diagnostic system developed and tested for mechanical (return channel jam, spalling) and sensor faults (bias, drift, scaling, loss-of-signal)
- Various motion profiles, load levels, and load types (spring or constant) were used in testing
- Results show the following overall rates: 3.46% false positive, 1.21% false negative, 0.29% misclassification, 3.8% unidentified

Implementation

Prognostic System Development
- The PHM system will employ a variety of algorithms (Kalman filters, Particle filters, neural networks)
- The influence of sensor noise and operational environment is being incorporated

Modeling
- Physical models: return channel wear, ball collisions, jam formation, vibration signatures, backlash, and lubrication deterioration
- Simulink models: T200 controller

Testing
- A Boeing 727 aileron wing section is being used as a development test bed
- Flight test planning being initiated on C-17, F-18, S-3, as well as on UH-60 helicopters and several unmanned aircraft

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