BAE Systems Platforms & Services

Pointing Accuracy Analysis for a Commander's Independent Weapon Station Demonstrator

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Introduction

- This presentation provides an overview of the modeling and simulation approach used to predict pointing accuracy of a Commander's Independent Weapon Station (CIWS) demonstrator developed to integrate a sensor payload with a weapon system on a high precision pointing gimbal
- DRS developed the CIWS sensor payload and BAE Systems the pointing gimbal
- CIWS provides the Commander a panoramic 360° stabilized sight capable of day / night engagements with the remotely operated M240 commanders weapon, or the vehicle main gun

Modeling Approach

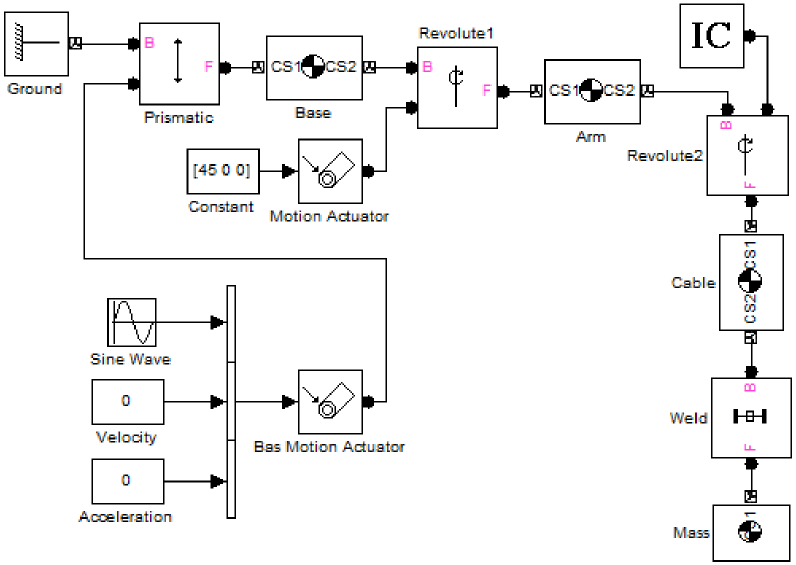
- Estimating pointing accuracy is a multidimensional problem with interactions and trade offs between the systems involved
  - For example, a high bandwidth controller will improve disturbance rejection but increase sensor noise sensitivity
- A high fidelity physics based model of the end to end system is required to evaluate a design and identify drivers to performance
- An error budget approach where each potential contributor is identified has been used to optimize the CIWS design
- Prototype testing has validated this approach

Error Sources
Mechanical Effects
Center of Gravity Offsets
Structural Deflection
Joint friction
Controller Loop Effects
Bandwdith
Sample Rate
Quantization
Amplifier and Motor Effects
Torque Loop Bandwdith
Sample Rate
Current Command Quantization
Current Command Transport Delay
Motor Slew Rate Limits
Sensors
Gyro Errors
Encoder Errors
Boresight / Calibration Errors
Extrenal Error Sources
Mobility Disturbance
Main Gun Firing
Own Gun Firing

Mechanical System Model

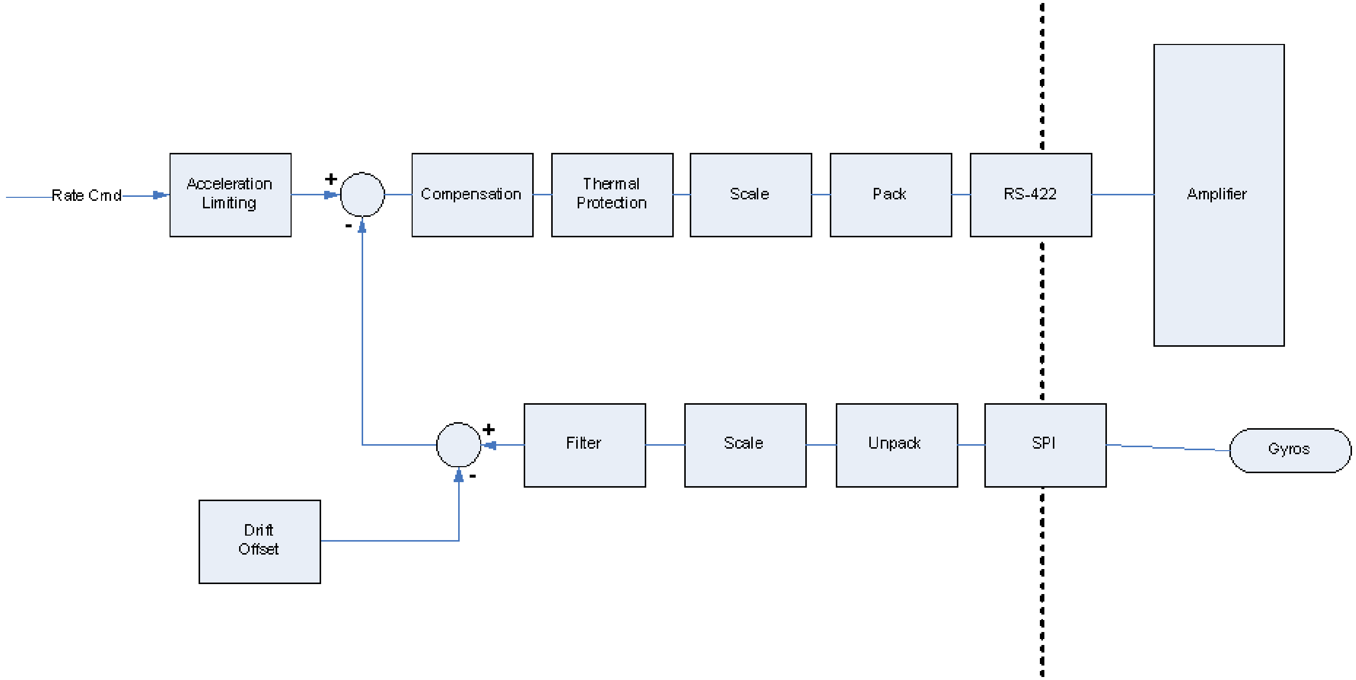
- The mechanical system is modeled as a multi-degree of freedom, flexible body system or rigid body system using Matlab SimMechanics
- Mass properties are imported from the PRO-E CAD model
- Spring-dampers between bodies are tuned to match the FEA modal predictions
- SimMechanics performs the derivation of the equation of motions based on the assembled system
- Sensor truth data at mounting locations is exported
- Base disturbance and motor torque inputs are used to drive the mechanical system

Generic Example of a SimMechanics Model



Control System Modeling

- Controller bandwidth is the key performance driver for disturbance rejection
- Frame rate and quantization errors are secondary error sources
- A complete digital controller for each axis of control has been developed and implemented in Matlab / Simulink



Power Electronics and Motor Modeling

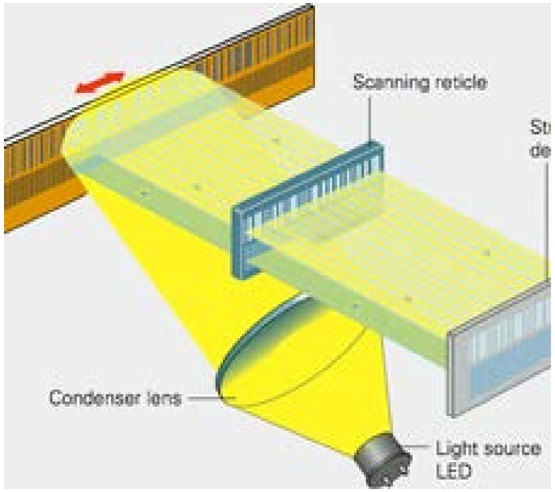
Torque Loop

Motor Electrical Model

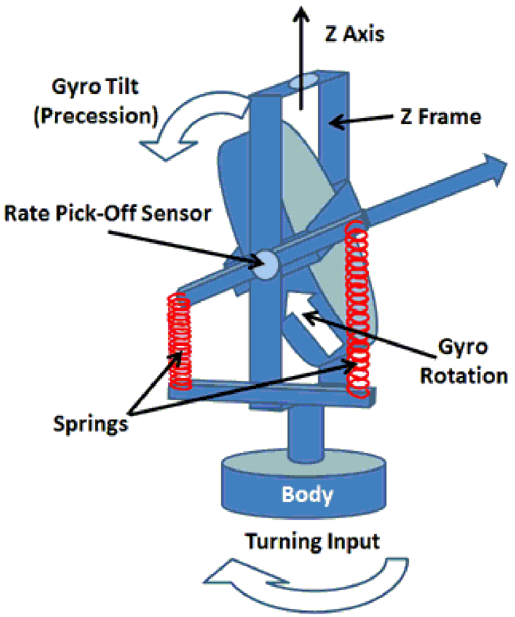
- Amplifier torque loop and motor electrical model
  - Torque loop bandwidth and slew rate limit from motor inductance performance drivers
  - Torque loop frame rate, quantization and latency in current command to the amplifier are secondary effects
  - Motor speed-torque envelope selected to accommodate worst case disturbances

Sensors Modeling

- System employs optical encoders and a two axis gyro to sense position and rates
- Dynamic response is modeled as a transfer function
- Detailed error modeling of each device includes those sources identified



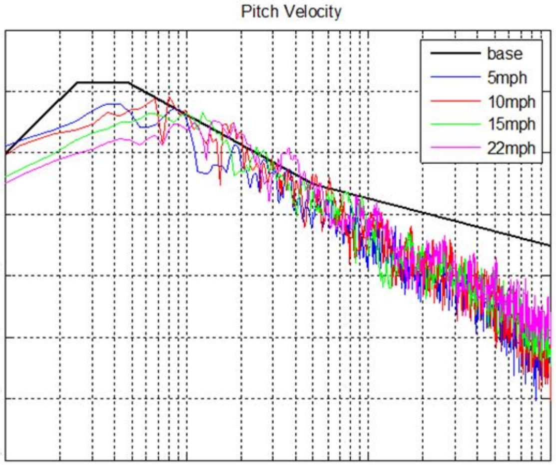
Encoder Error Sources
Encoder Accuracy
Encoder Noise
Encoder Quantization
Encoder Swash
Encoder Temp Sens



Gyro Error Sources
Gyro Noise
Gyro Alignment
Gyro Scale Factor Linearity
Gyro Non-G Drift Bias
Gyro Direct G Sensitivity
Gyro Quadrature G Sensitivity
Gyro G^2 Sensitivity
Gyro Quantization

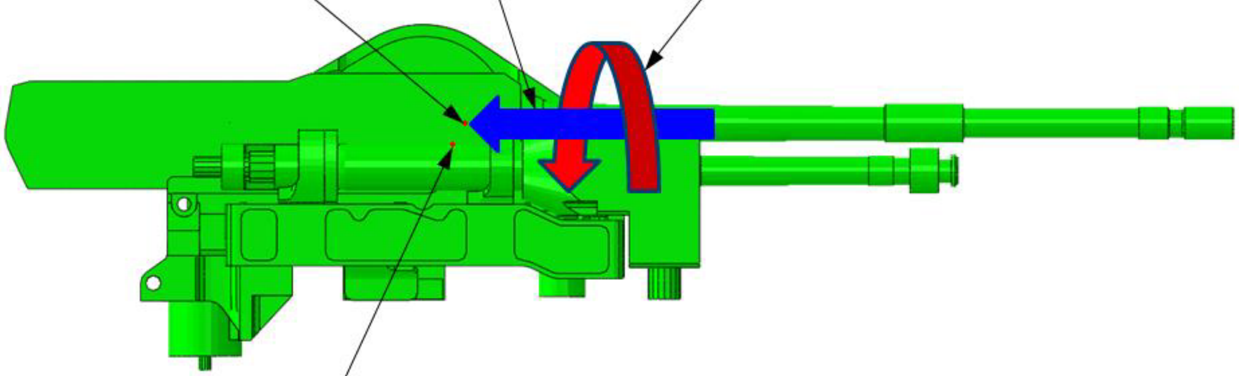
Base Disturbance – Mobility and Main Gun Fire

- Separate LMS Virtual.Lab Motion software used to model vehicle
- Hull, weapon and sights represented as rigid bodies
- Motion track super element utilized to model suspension (track and road arms)
- Imported hull top plate and turret body models from NASTRAN structural models
- Analysis of vehicle driving on various terrains and effect of main gun fire impulse loads
- Model Outputs
  - 6DOF motion data from various locations such as the CIWS mount location and hull CG
  - Transient data may be utilized to excite separate component models
  - Power Spectral Density analysis may be utilized to analyze frequency content



CIWS Weapon Firing Disturbance

- Own gun firing disturbance modeling shows disturbance is dominated by recoil stiffness (recoil distance), rate of fire, recoil damping and gun center of gravity
  - Increased recoil stiffness (shorter stroke) increases pointing jitter and increases the torque requirements of the motors
  - Decreased recoil stiffness (longer stroke) increases the ammo feed risk, increases mass, and potentially lowers modal frequencies



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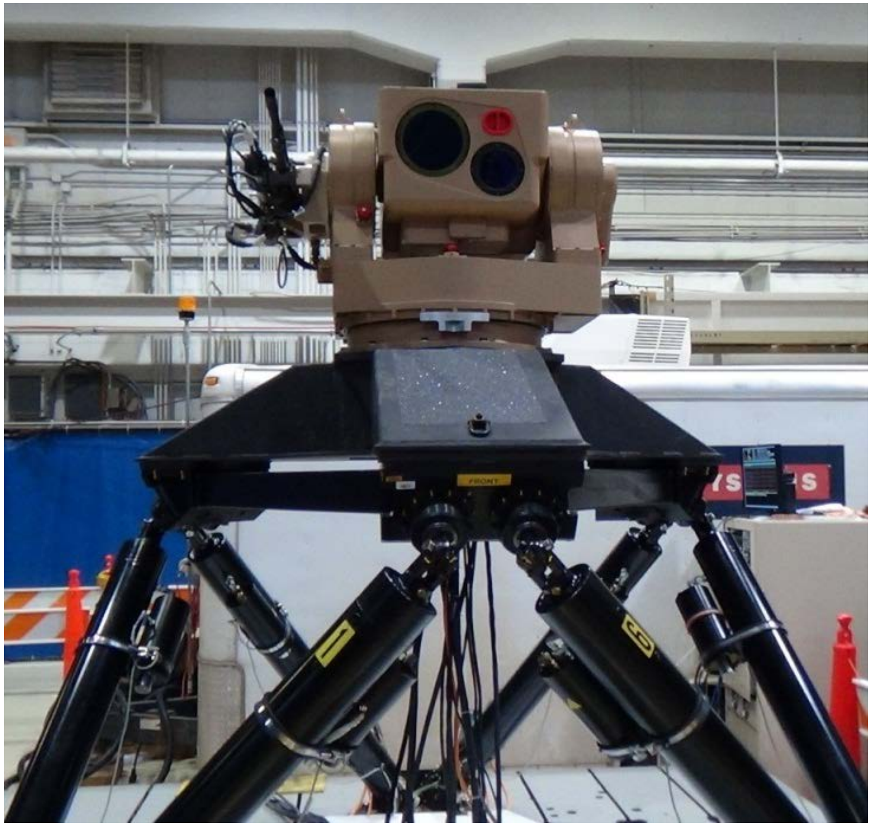
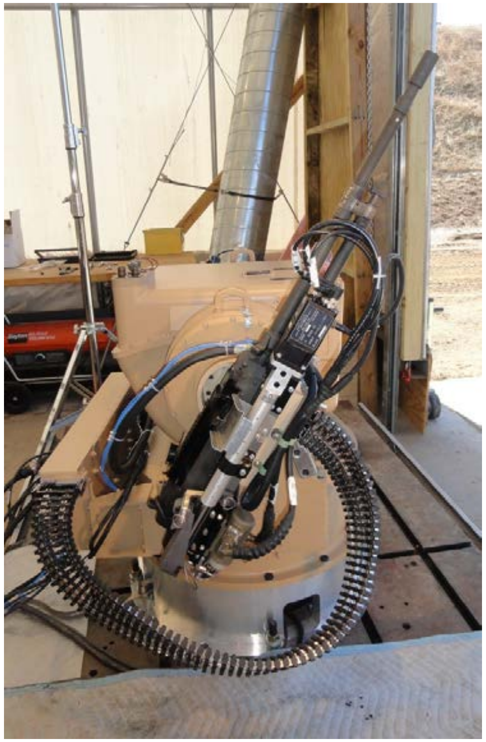
Mobility Disturbance Pointing Validation

- Assessed gimbal stabilization performance on a 6DOF motion table programmed to provide an input disturbance profile
- Collected RMS LOS stabilization of gimbal from gyro feedback
- Collected FLIR and DVC imagery to calculate the LOS motion of a target board
- Correlated simulation predictions against test results



Camp Ripley CIWS Live Fire Testing

- Fired rounds in Single Shot, Burst and Continuous fire at 0°, 35°, & 60° elevation
- Excellent pointing repeatability/accuracy
- Correlated simulation predictions against test results
  - Gun pointing accuracy and image stability while firing



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