37th Gun and Ammunition NDIA Symposium

Multi-Role Armament & Ammunition System (MRAAS)

Weapon Stabilization Assessment

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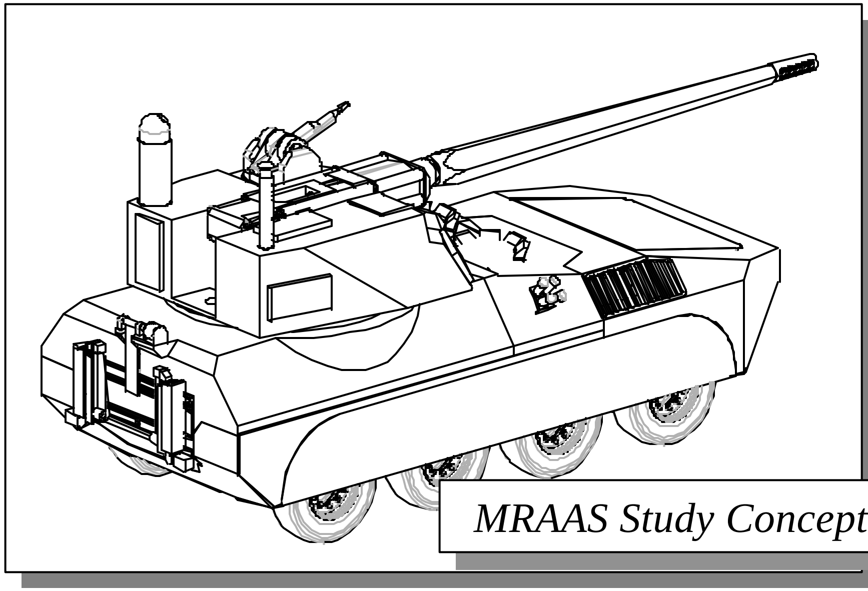
Contents

Background

U.S. Army Transformation requires transition to highly transportable fighting force.

The Future Combat System (FCS) is the intended objective - “system of systems” to meet a variety of missions.

Multi-Role Armament & Ammunition System (MRAAS) under development by U.S. Army ARDEC to meet FCS LOS Direct Fire and BLOS/NLOS Indirect Fire lethality requirements.



MRAAS Study Concept

MRAAS Multi-Mission ATD features:

- Turret Mission Module for integration into light vehicle
- 105 mm cannon with swing chamber
- CTA munitions for direct/indirect fires
- LOS kills out to 4-5 km, BLOS kills out to 50+ km
- <u>C-130 transportable, with 19 ton total system weight.</u>

Main Objectives

As part of 6 Month MRAAS Concepting Study Contract:

- Determine system dynamics impact of integrating a large caliber gun system onto a lightweight ground vehicle.

- Evaluate weapon stabilization performance of MRAAS, including sensitivity to:
  - Gun unbalance due to CG offset from trunnion axis.
  - Disturbances due to vehicle motion over terrain.

Requirements

- Per the MRAAS Turret Mission Module – Weapon Control Request For Proposal:
  - Fire Control System shall support LOS engagements under dynamic conditions with no greater than θ_{total} mils error, 1 sigma Root Mean Square (RMS).
  - Muzzle stabilization error shall be no more than θ_{stab} mils RMS.
  - Indirect fire requirements less stringent.

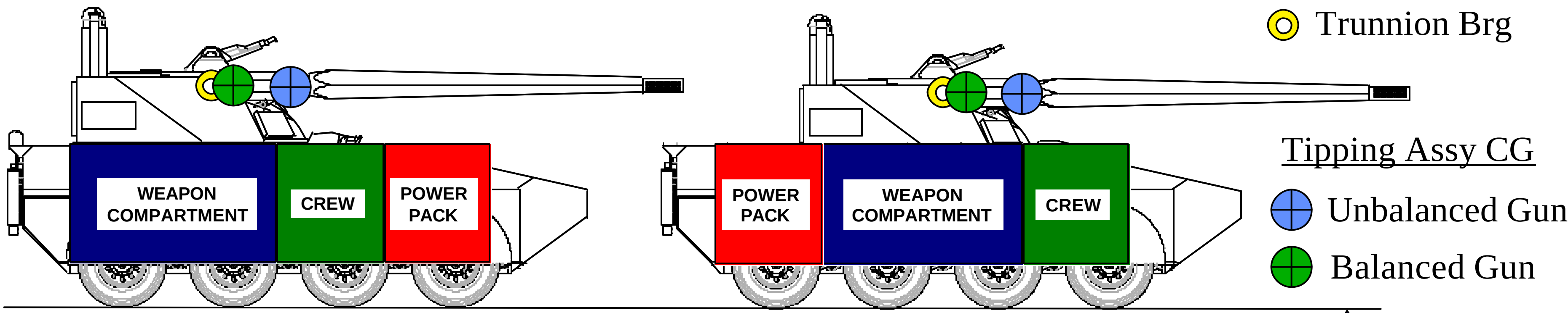
- Dynamic Condition Assumptions:
  - Fire On The Move vehicle speed varied 5 to 30 mph.
  - APG Munson Gravel Course and RRC-9 Stabilization Bump Course terrain models used to span roughness.

Vehicle Dynamics Model: Vehicle Concepting

Key Assumptions:

- MRAAS turret concept mounted in mid and rear locations on wheeled chassis, with balanced/unbalanced armament (CG forward of trunnion
- Appropriate mass property and space claim adjustments made:

Concepts I & II **Concepts III & IV**



Concept	Turret Location	Gun Unbalance
I	Rear	Unbalanced
II	Rear	Balanced
III	Mid	Unbalanced
IV	Mid	Balanced

Unbalance Most Signicant Effect For Stabilization

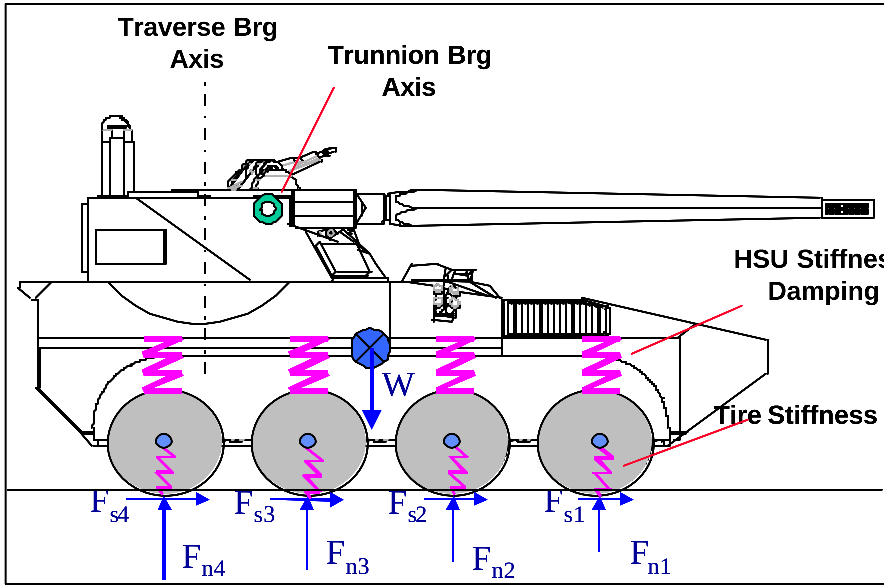
Vehicle Dynamics Model: DADS Development

Key Vehicle Dynamics Assumptions:

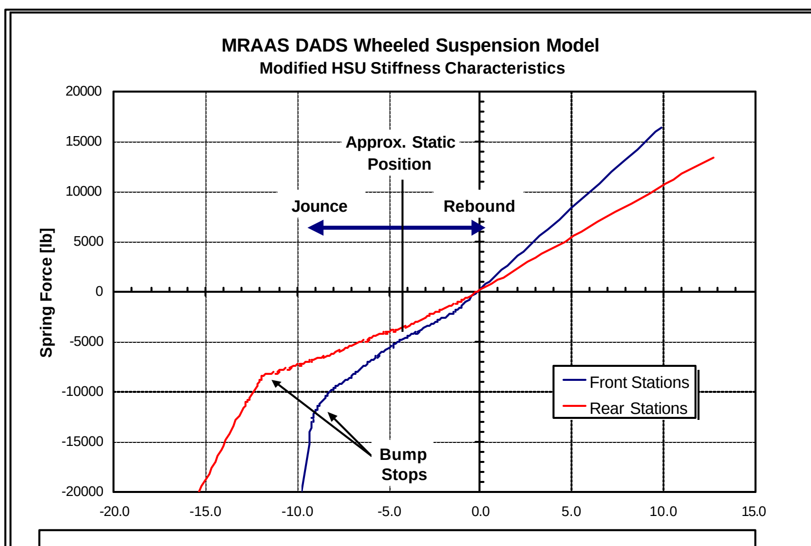
DADS rigid body chassis model.

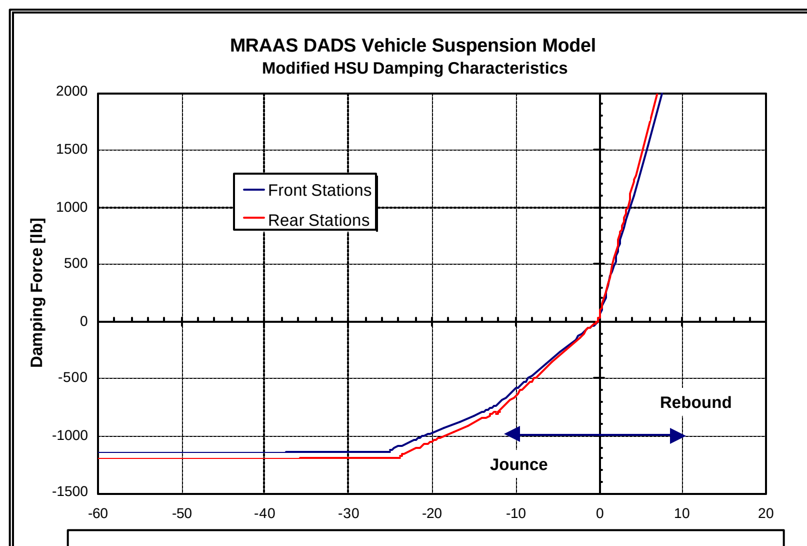
Simplified wheeled suspension model capturing hydropneumatic non-linear stiffness and damping characteristics

- Heave natural freq. ~ 1.5 Hz (translation)
- Pitch natural freq. ~ 0.75 Hz (rotation)
- Near critical damping
- Tire stiffness & damping.



Vehicle Dynamics Free Body Diagram





Vehicle Dynamics Model:
DADS Platform Disturbance Estimate

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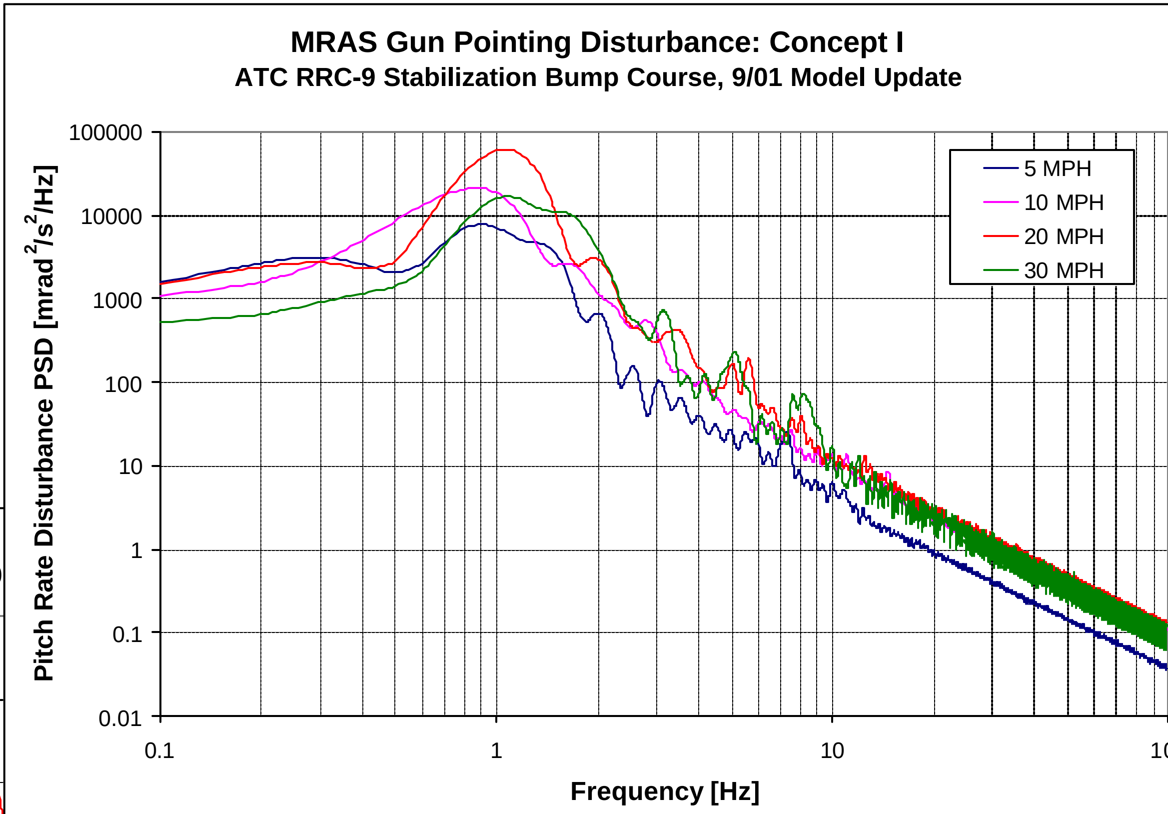
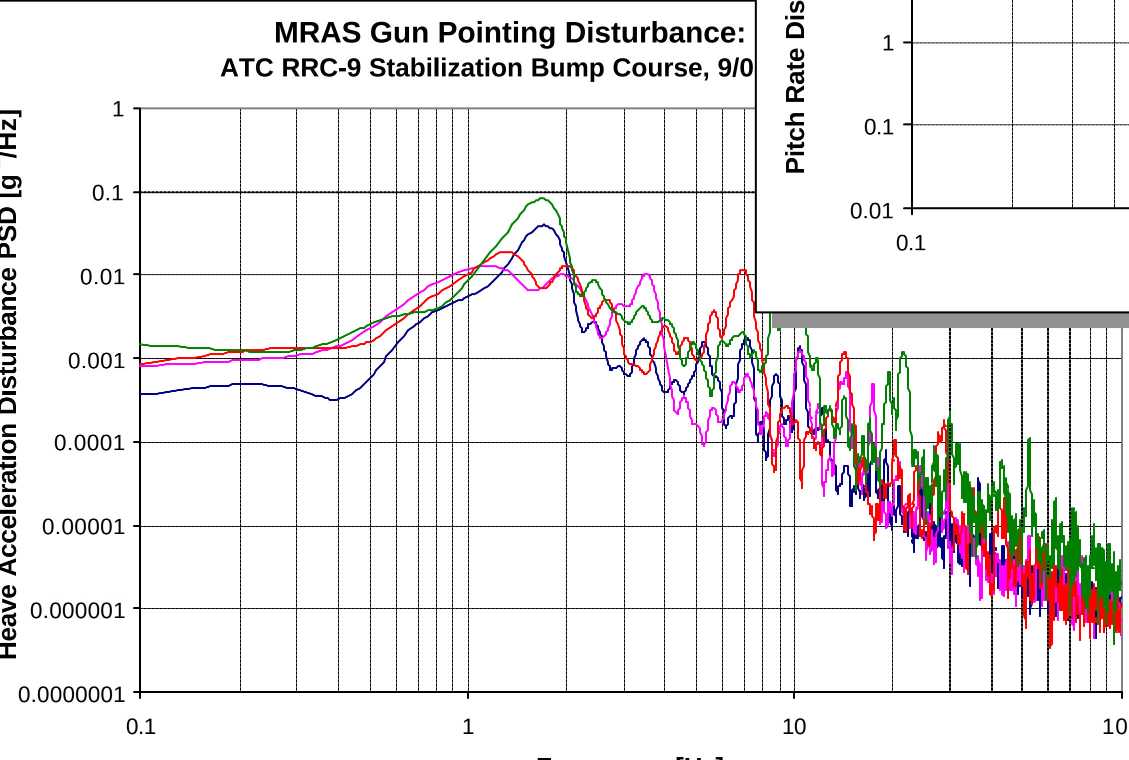
- Vehicle *Pitch Rate* Disturbance Power Spectral Density (PSD)



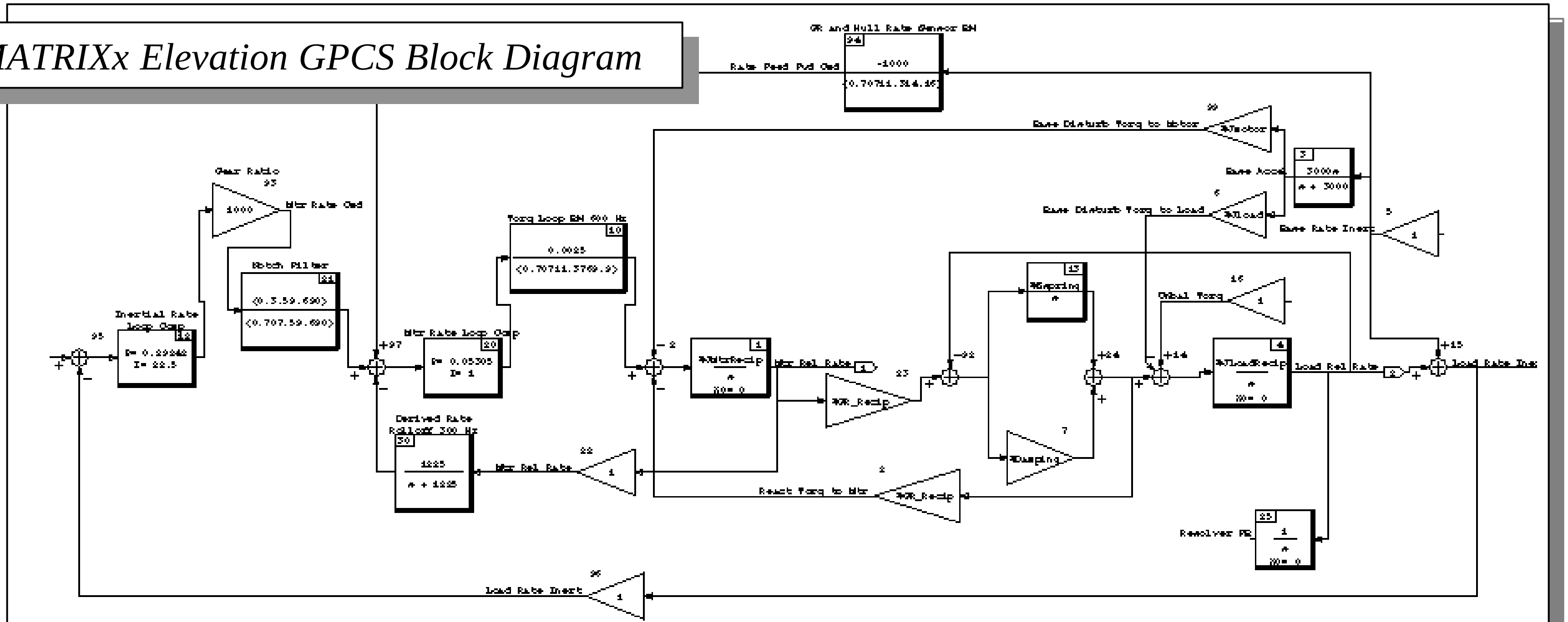


- Vehicle *Heave Acceleration* Disturbance PSD

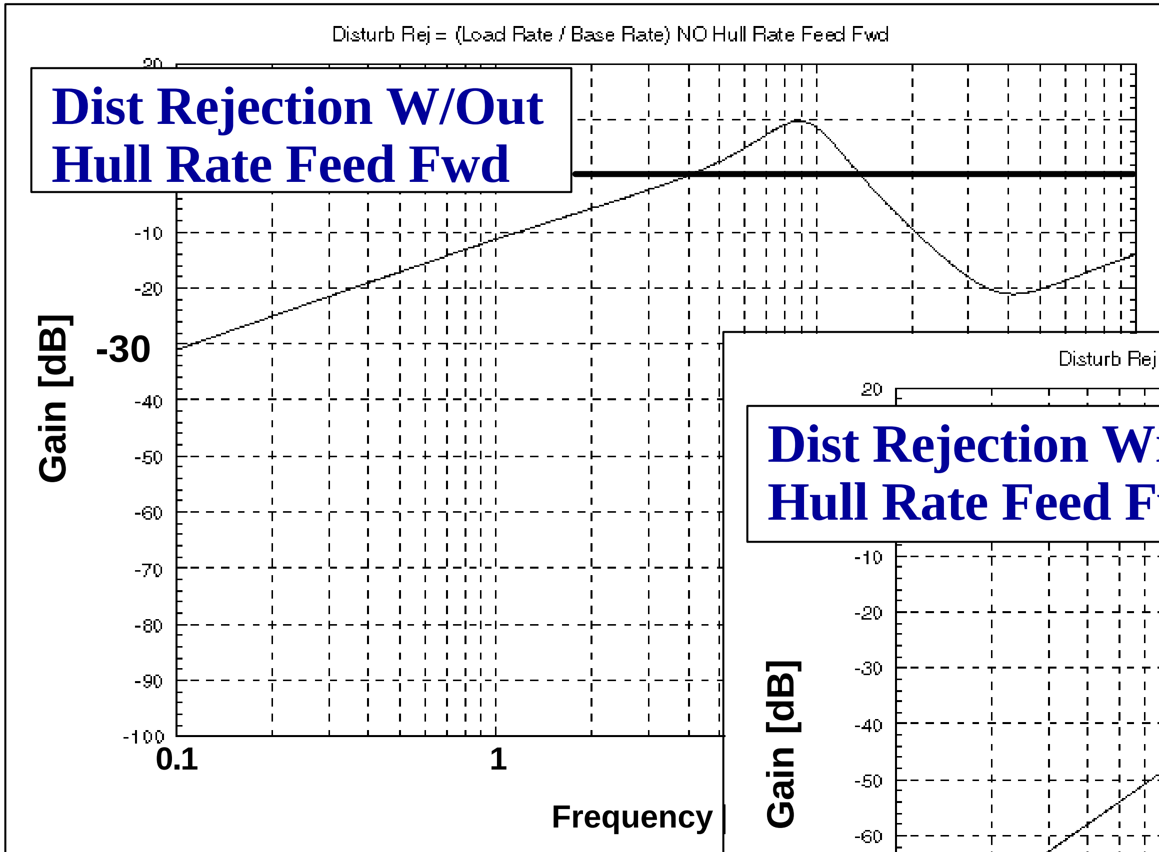
Gun Pointing Control System Model: MATRIXx Development

- Preliminary Elevation GPCS Model created in MATRIXx.
- Outer Gyro Rate P+I Loop (inertial) wrapped around Inner Motor Rate P+I loop (relative).
- MATRIXx model includes:
  - Plant dynamics with variable drive compliance, gear reduction
  - P+I compensation with notch filter
  - Hull rate feed forward sensor with roll-off.

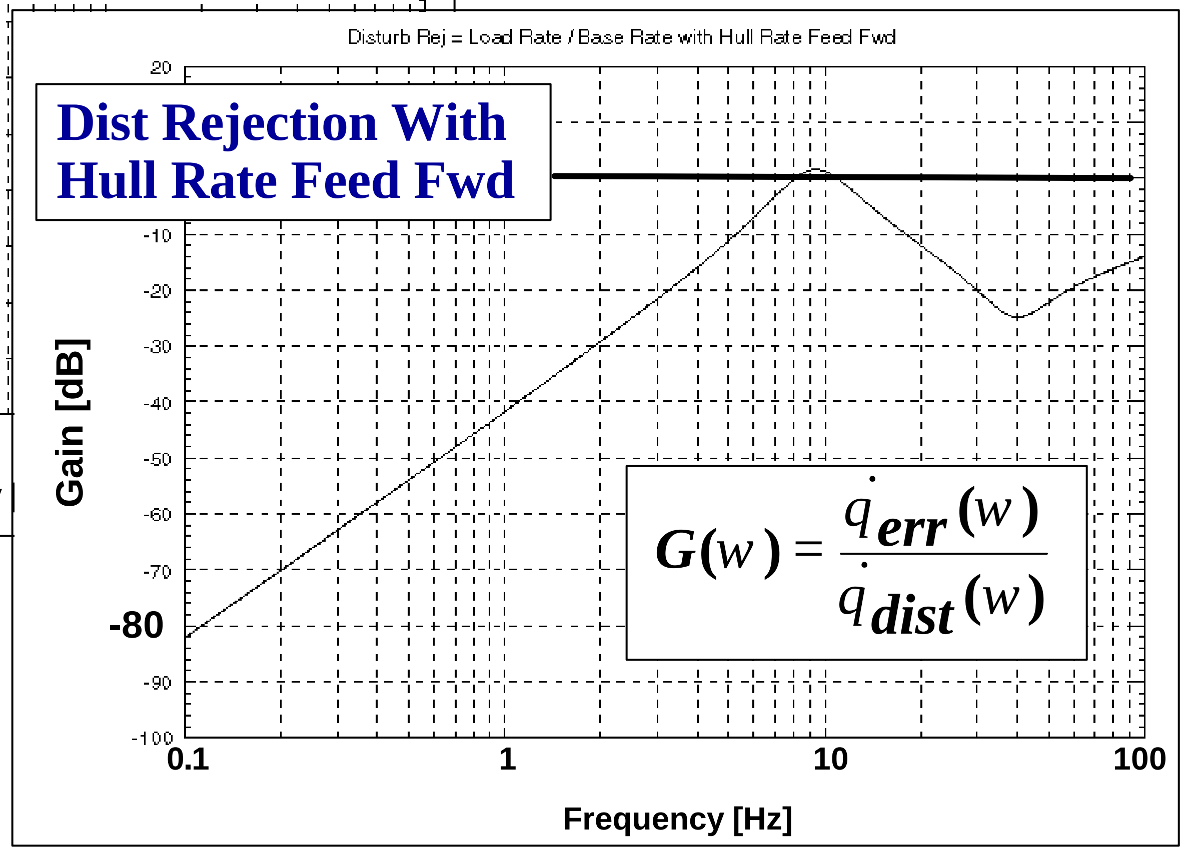
MATRIXx Elevation GPCS Block Diagram



Gun Pointing Control System Model: GPCS Disturbance Rejection Estimate

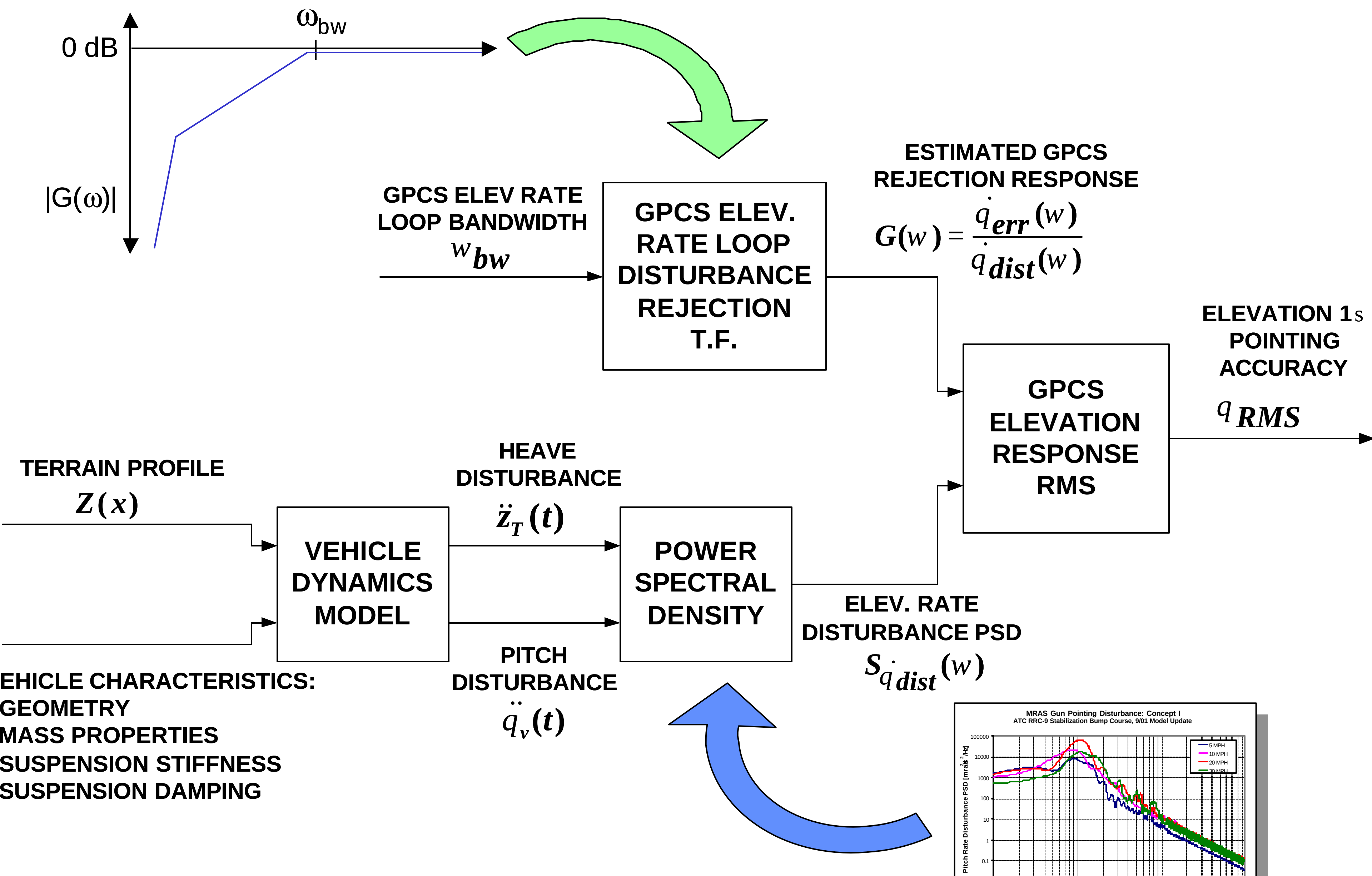


- MATRIXx model used to estimate platform disturbance rejection transfer function.



- Hull rate feed forward provides substantially greater rejection at low frequency.

Stochastic Pointing Error Estimation



Stochastic Error Estimation: Concept I Sensitivity to Terrain, Speed

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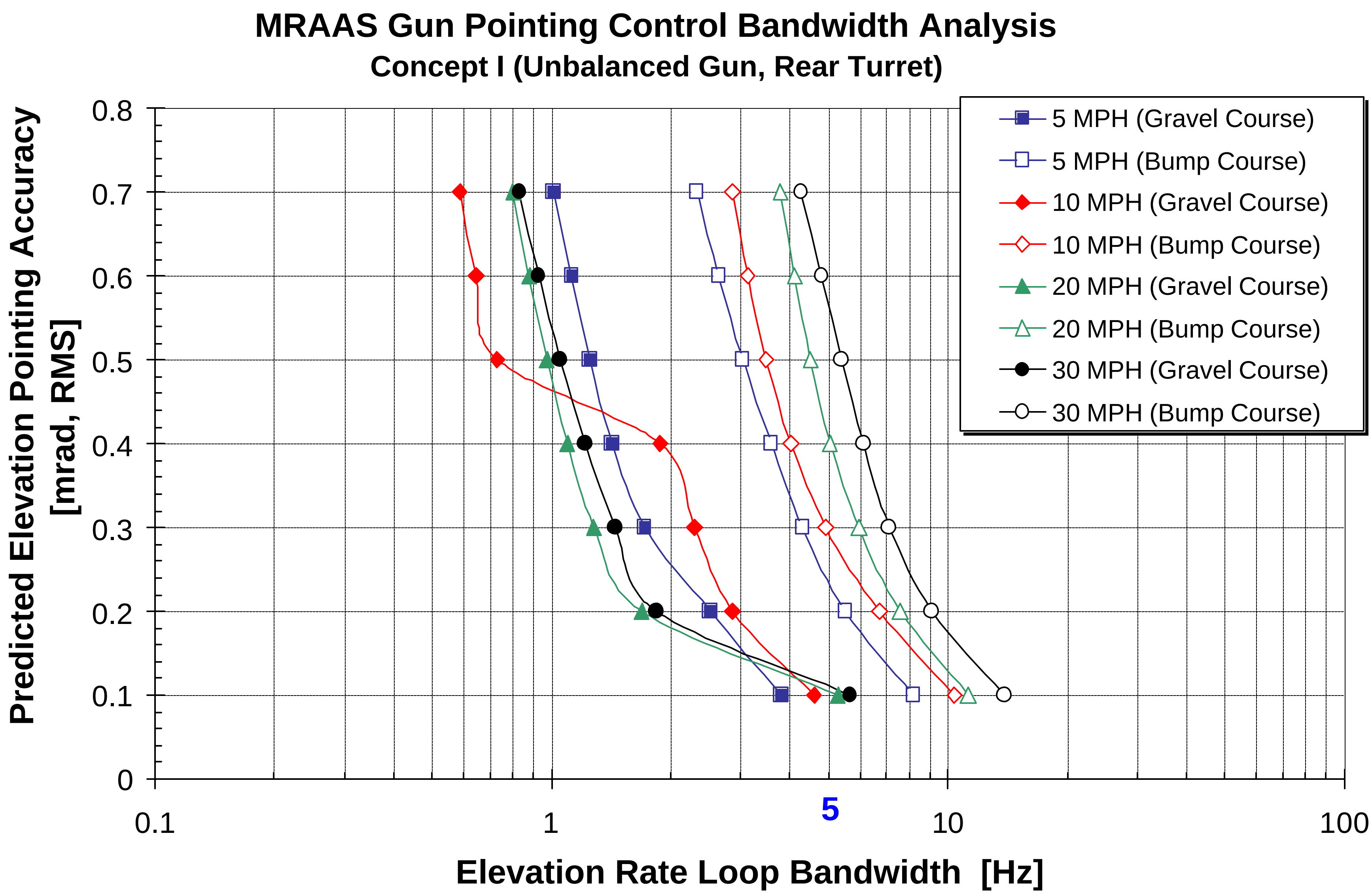
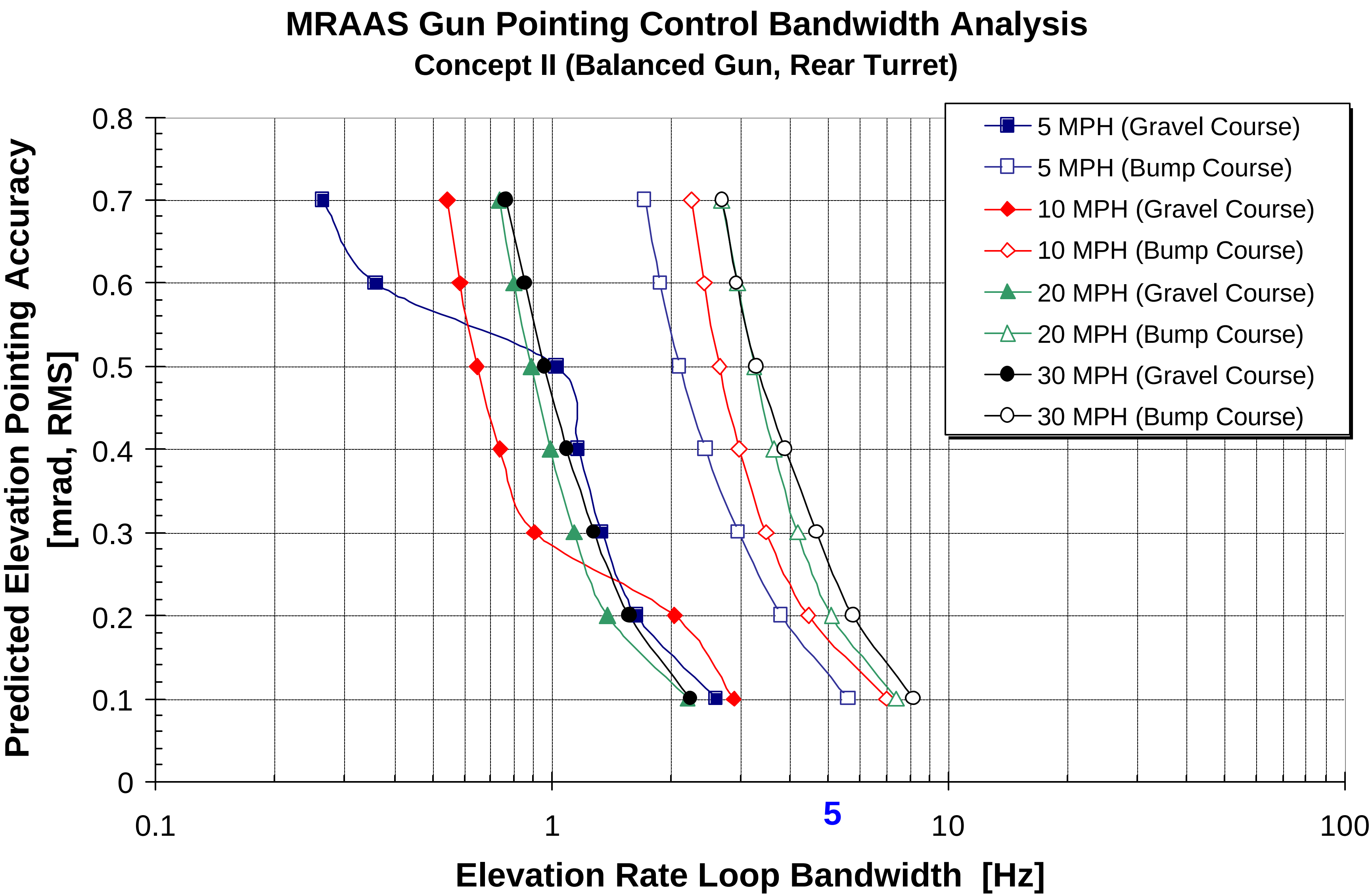


Stochastic Error Estimation: Concept II Sensitivity to Terrain, Speed



Platform Stability Analysis

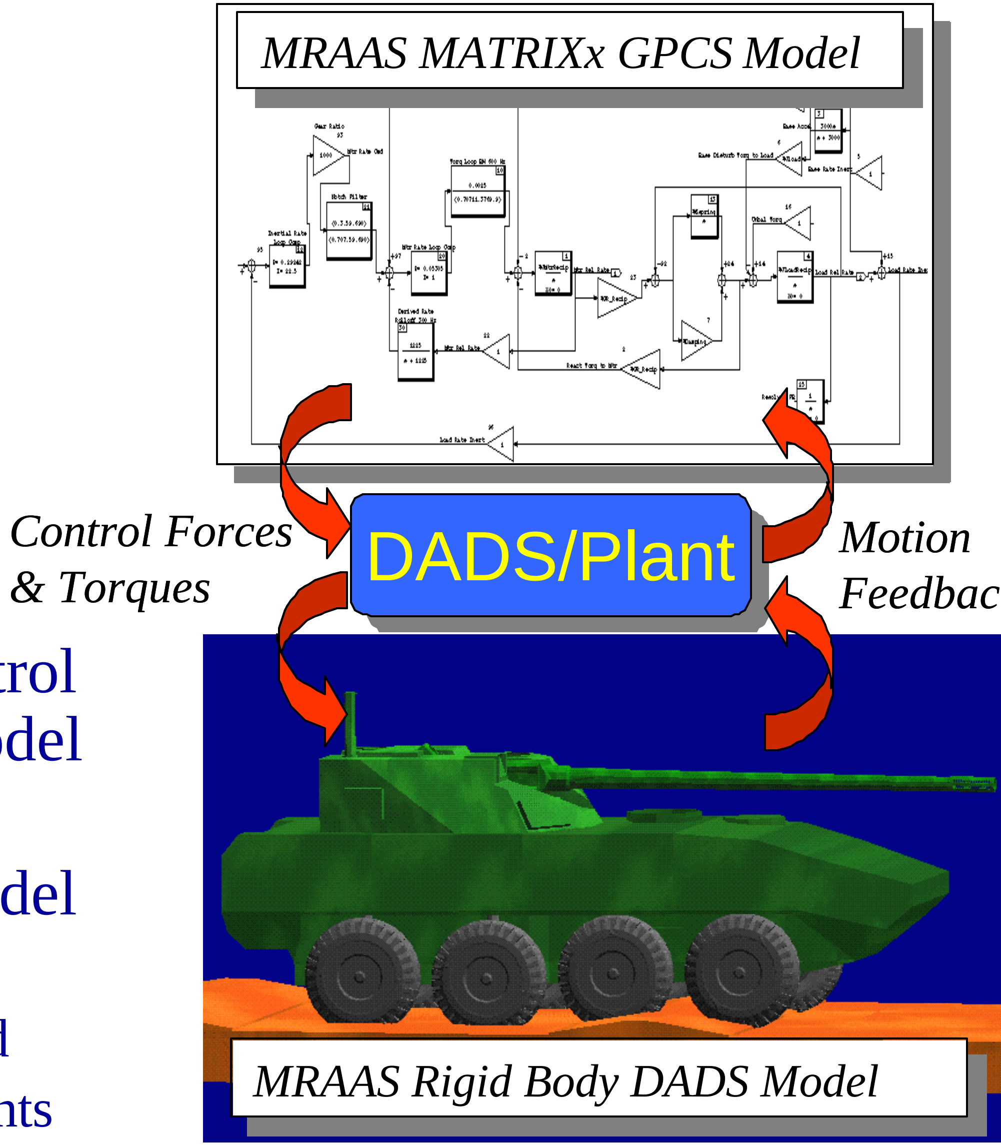
Stochastic method appropriate for concept-level parametric trades.

- Allows rapid assessment of multiple simulation scenarios.
- Assumes load motion does not significantly influence base motion (gun and chassis are uncoupled).

Next level of fidelity involves coupling MATRIXx pointing control model with DADS suspension model via DADS/Plant.

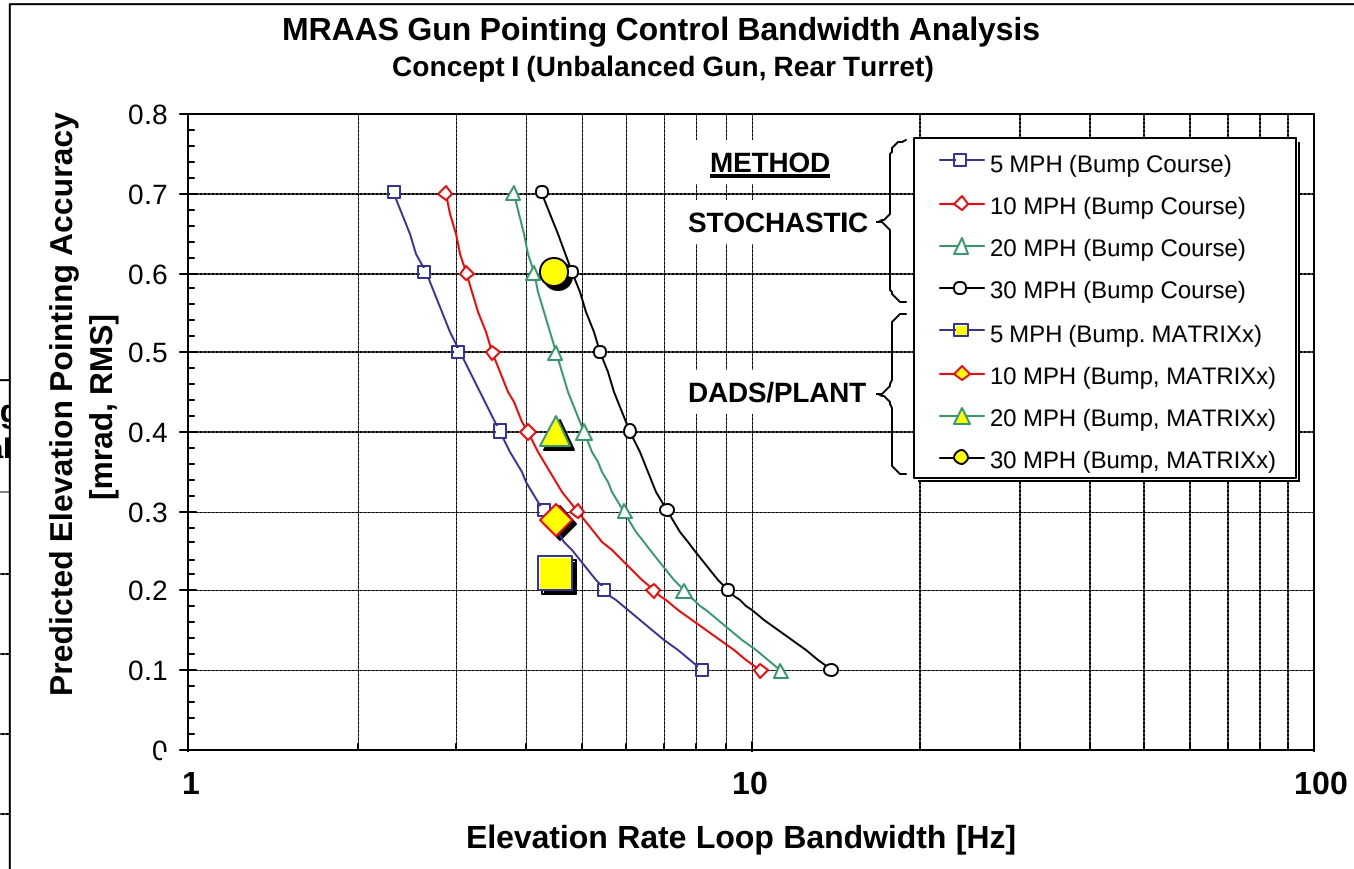
Resulting “Platform Stability” model used to:

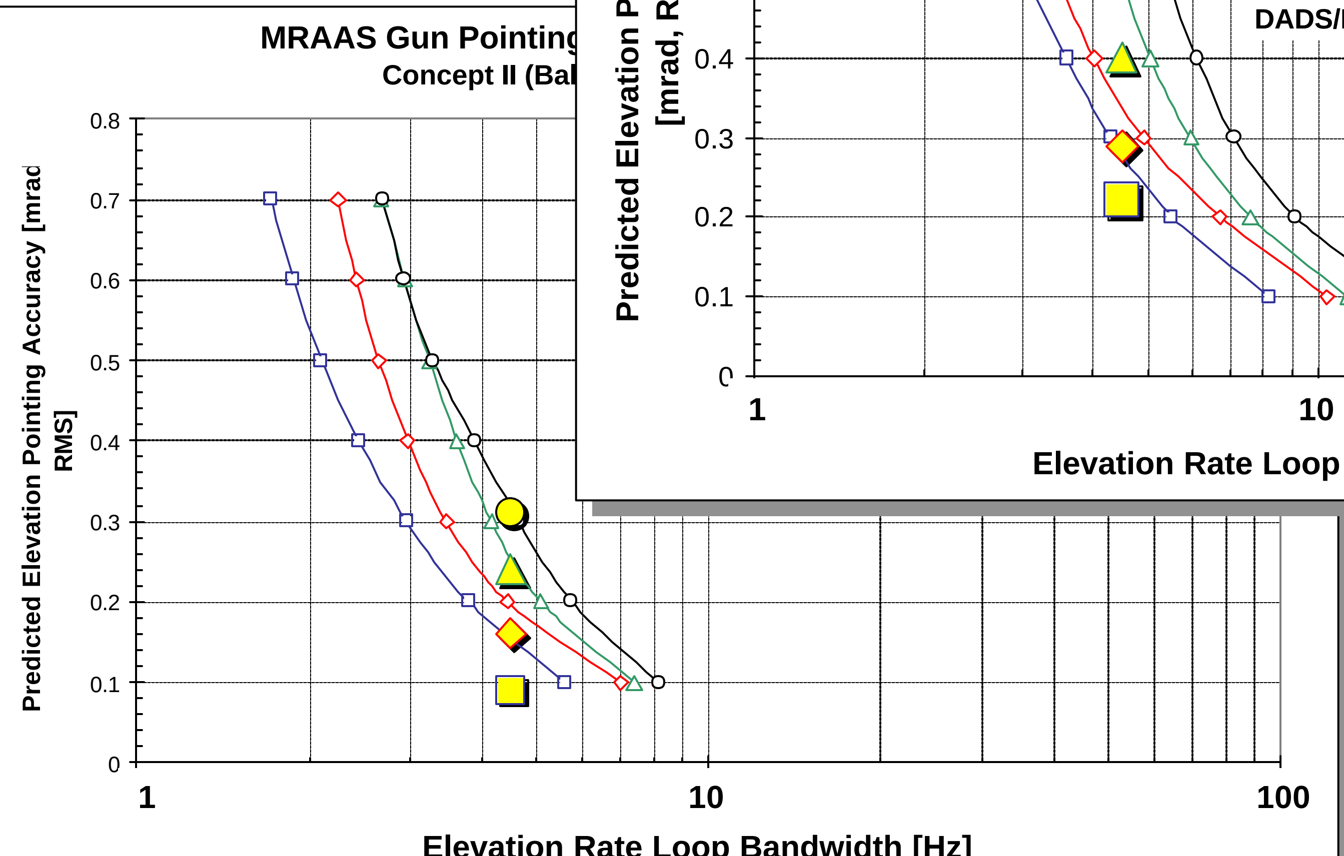
- Analytically verify stochastic method
- Estimate gun drive power requirements using Concepts I & II.



Platform Stability Analysis:
Stochastic Method Verification, Concept I

- Unbalanced Gun



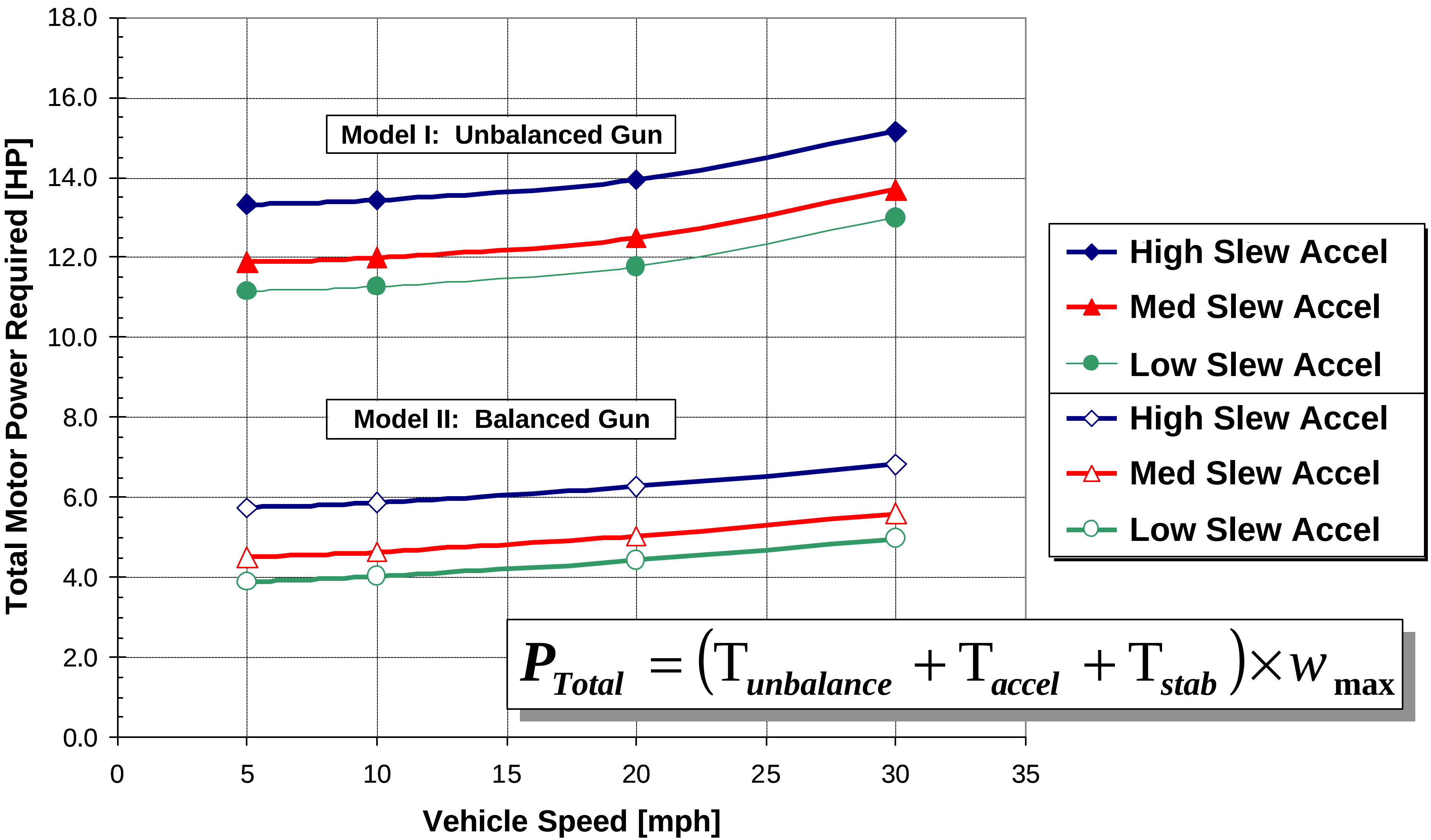


- Balanced Gun

Platform Stability Analysis: Elevation Drive Power Estimation

MRAAS Weapon Stabilization Power Estimation

RRC-9 Bump Course, 10 Hz 1st Mode, 70% Assumed Overall Efficiency



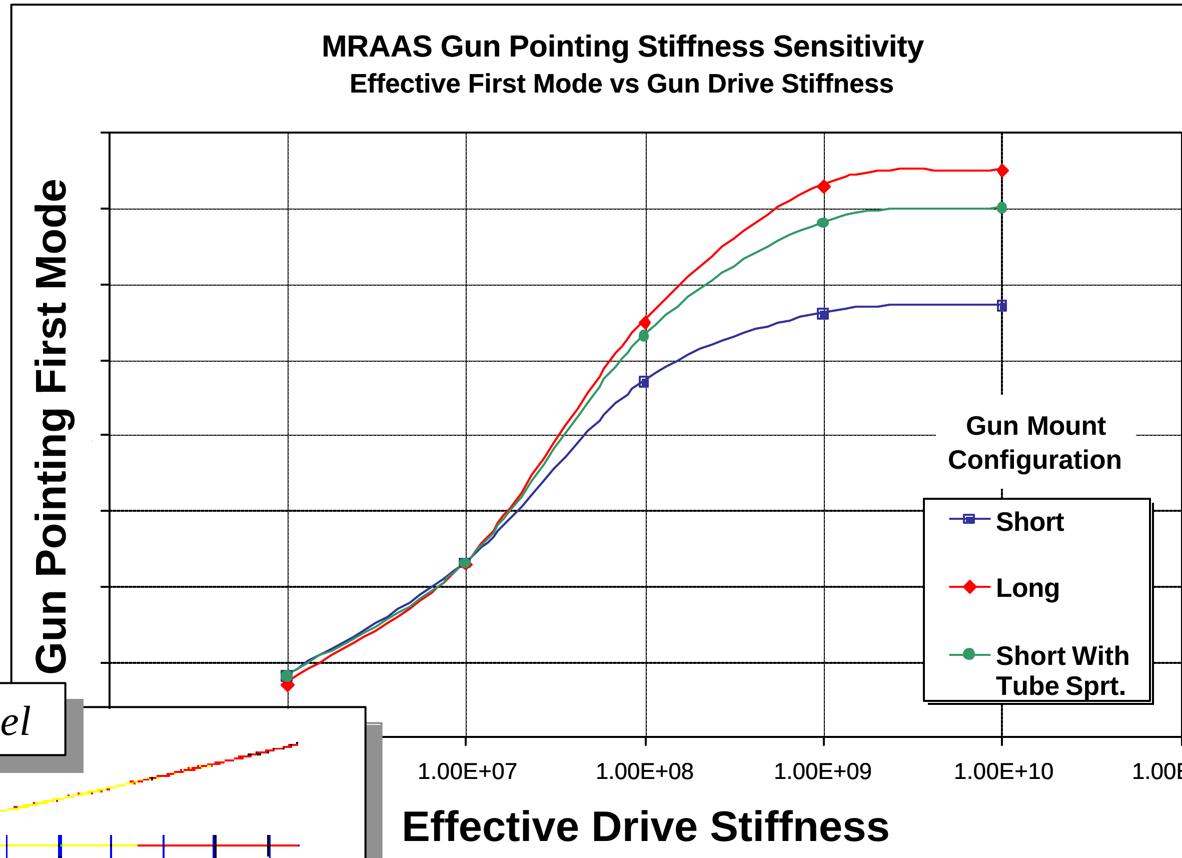
$$P_{Total} = \left(T_{unbalance} + T_{accel} + T_{stab}\right) \times w_{\max}$$

Gun Pointing Stiffness Study

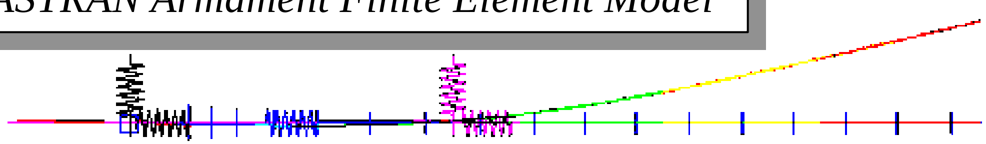
- Minimum 1st natural frequency of the gun pointing system is constrained by the controller bandwidth.
- The gun pointing system natural frequency is determined by the flexibility of: Gun Drive Actuators, Turret, Gun Mount, Cannon

A parametric study using a NASTRAN FEM was used to investigate first mode sensitivity to:

- Elevation Drive Stiffness
- Mount/Cannon Stiffness
- Mount Extension Length
- Mount Bearing Locations



NASTRAN Armament Finite Element Model



Platform Stability Analysis Demo: DADS/Plant w/Stabilized Flex Body

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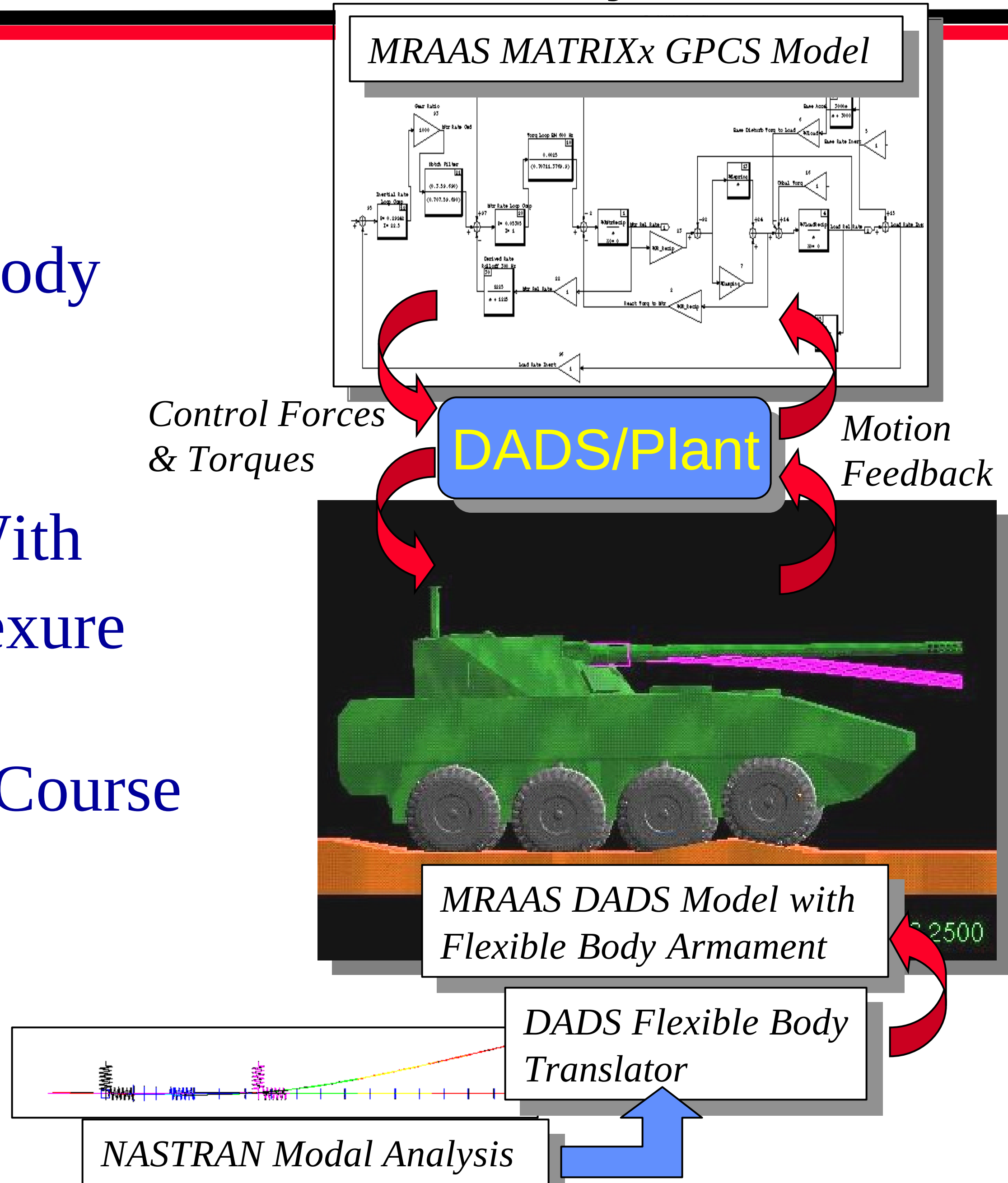
DADS/Plant Flexible Body Demonstration

Active Gun Pointing With Armament Structural Flexure

APG RRC-9 Stabilization Course



Platform Stability Analysis Demo: DADS/Plant - Stabilized Flexible Body

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MRAAS Configuration-I Model

30 MPH over RRC-9 Bump Course

(Flexible Gun with Stabilization)

(Deformation Scale = 1)

Conclusions

- Stochastic error estimation method provided rapid concept-level gun pointing performance estimation.
- Reducing gun CG offset from trunnion could reduce req'mts for:
  - Bandwidth & pointing stiffness by up to 25%
  - Maximum drive power by up to 50%
  - Trunnion vertical accelerometer (vertical acceleration feed forward).
- Parametric FEA modeling used for early estimation of optimal gun pointing component stiffnesses.
- Coupled modeling approach provided improved fidelity by leveraging subsystem models.
- Next step is to incorporate a Muzzle Reference Sensor with armament flexure response in the pointing control model.
- Using this approach, the disturbance rejection benefit of an active suspension system can also be evaluated.

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