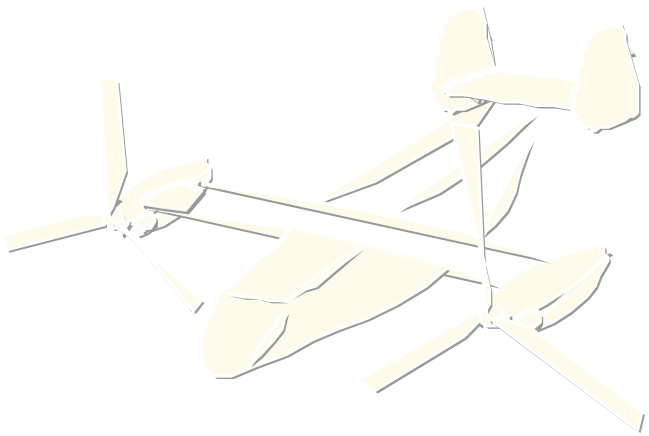
AIAD: A Look in Tiltrotor & Aeroelastic Phenomenon



By

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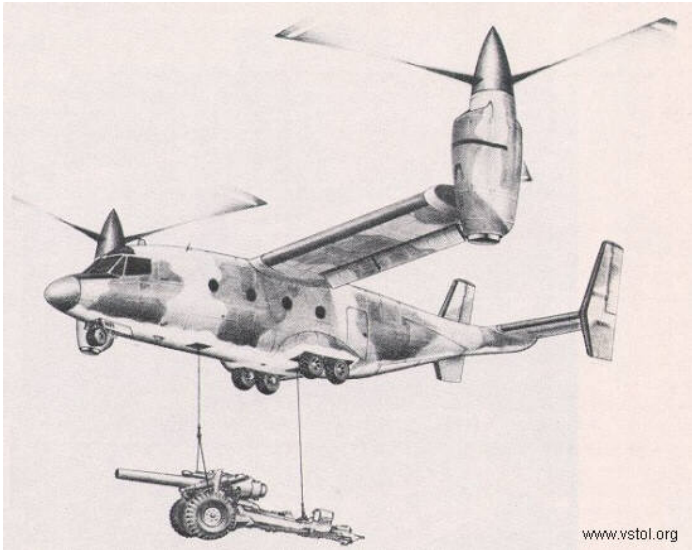
Agenda

VEHICLE TECHNOLOGY DIRECTORATE

- PURPOSE
- PROJECT BACKGROUND
- PROBLEM STATEMENT
- TESTS and RESULTS
- TRANSONIC TUNNEL
- LEARNING POINTS
- FUTURE AREAS



Purpose

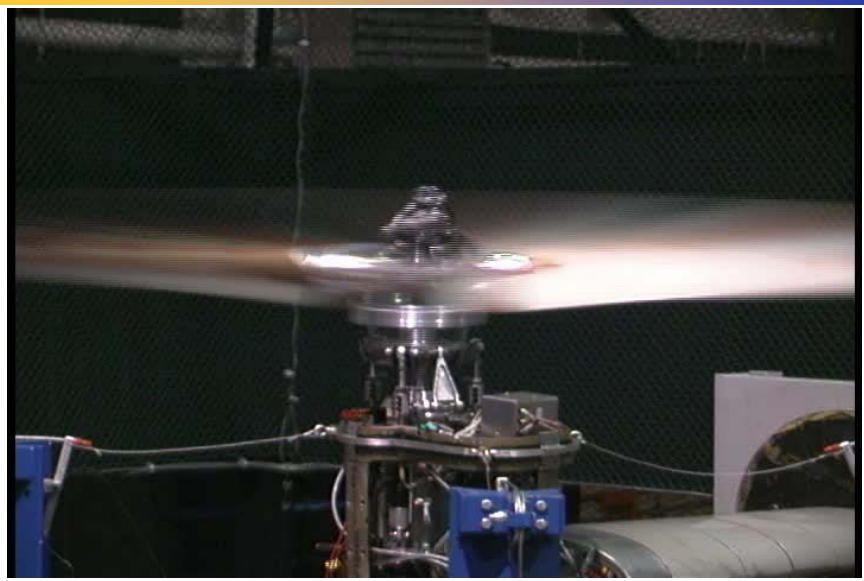
- To gain insight and experience in my Field of Study, Aerospace Engineering, and to come into contact with the real life application of what I have learned and new concepts that will help me in future classes.

- To work with engineers in the field on a real research project that has possible application to today's soldiers, and in doing so make future and past courses more meaningful to me.

- Project Team Objective - To collect and analyze data taken on the tiltrotor model, to identify the free play in the drive system

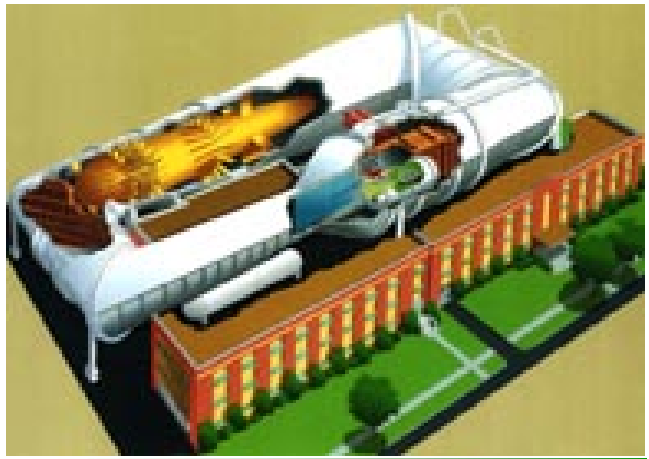
Whirl Flutter

- **DEFINE**
  - **Aeroelastic phenomenon**
- **CAUSE**
- **HAZARDS to AIRCRAFT**
  - **Instability that can lead to catastrophic failure and loss of aircraft**



Background

- **TRANSONIC DYNAMICS TUNNEL**
  - **CHARACTERISTICS**
    - **DIMENTIONS**
      - 16FT X 16FT
      - MAC # 0.2-1.2
      - REYNOLDS # (AIR) 0.03-3x10^6 / ft
    - **R-134A**
      - Stored as a liquid
      - REYNOLDS # 0.2- 10x10^6 / ft
    - **SLOTS**
  - **WHAT'S TESTED?**
    - **GROUND MODELS**
    - **SUSPENDED**
    - **SEMI-SPAN WALL-MOUNTED**



Transonic Dynamics Tunnel

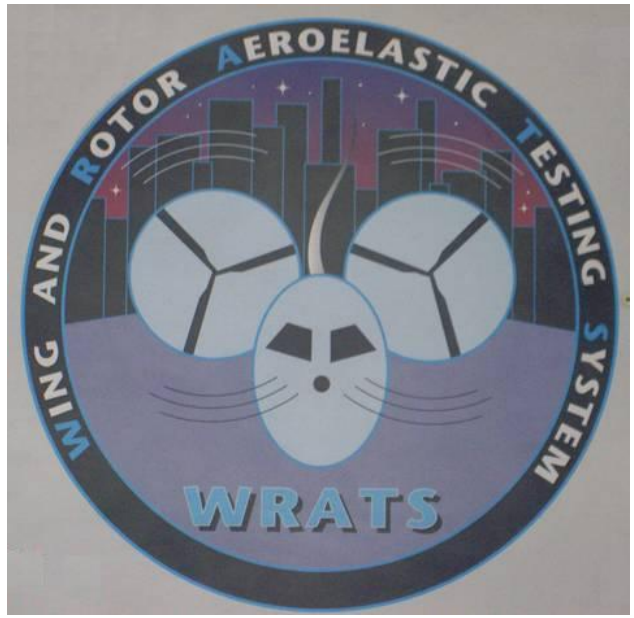
Tunnel Control Room

ARES Helicopter Model

Background

- **WRATS (Wing and Rotorcraft Aeroelastic Test System)**

- **Research to:**
  - Improve aeromechanical stability prediction tools
  - Experimentally validate analyses



WRATS System

- 1/5-Size Aeroelastically-Scaled Model of the V-22 FSD
- Semi-span with elastic wing and rotor blades, pylon dynamically-scaled, fuselage is rigid
- Design rotor speeds
  - 742 RPM cruise (airplane mode)
  - 888 RPM hover (helicopter mode)
- Rotor Diameter 7.6 ft.
- Max Speed 200 kts. model scale

- Operates in air and R134a Gas
- Produces accurate representation of full-scale aircraft with respect to aeroelastic stability and loads, both static and dynamic

Baseline vs. SASIP Hubs

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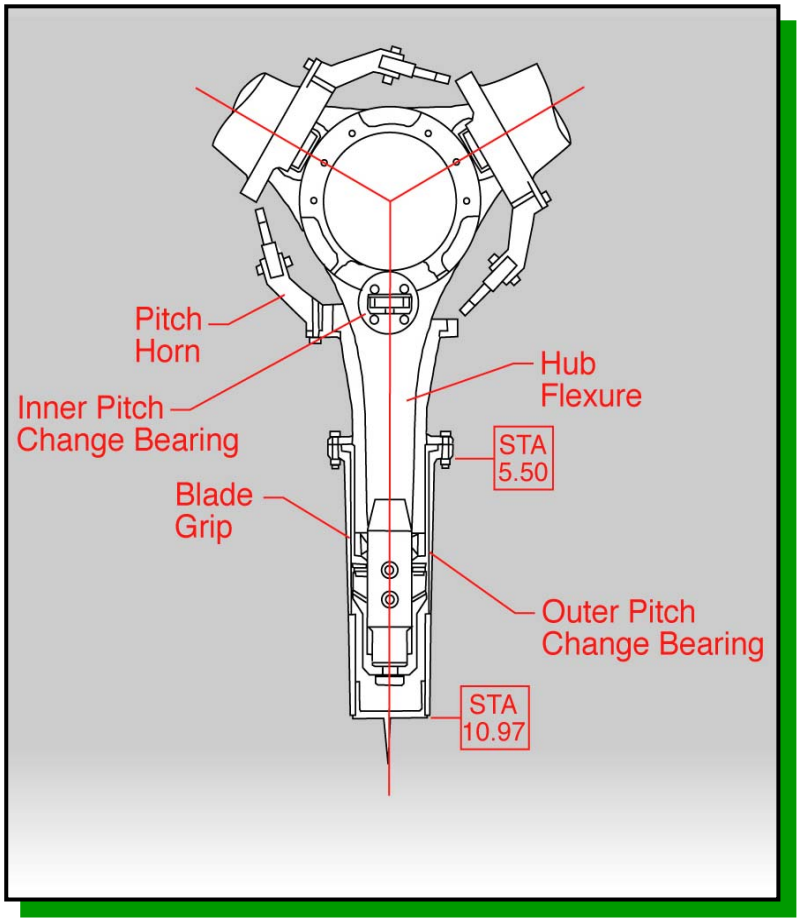
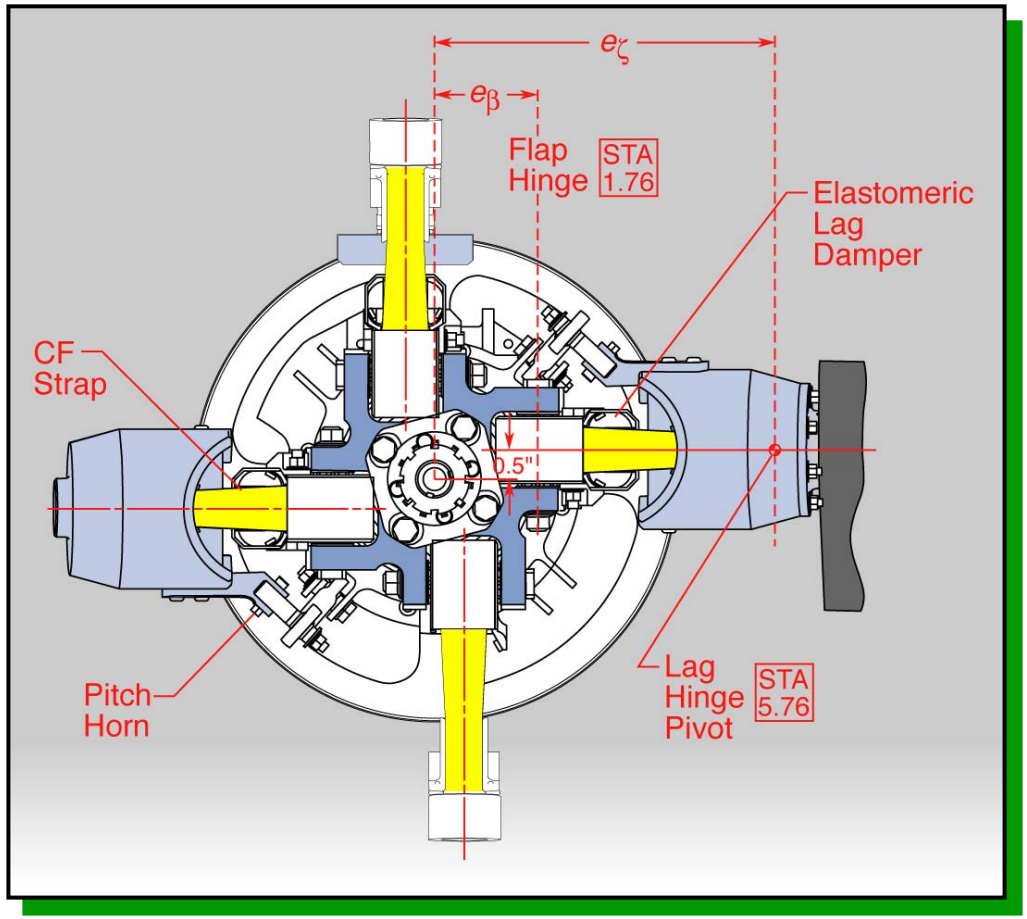
Baseline (V-22 type) Hub

3 bladed, gimbaled, stiff-inplane



Semi-Articulated Soft-Inplane Hub

4 bladed, articulated hinges, soft-inplane



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Motivation

- **Army - Joint Heavy Lift Rotorcraft Program**
  - Needed to carry Future Combat System (FCS) payload
  - 20 ton payload, 250 nm mission radius

- **NASA Vehicle Systems - Heavy Lift Rotorcraft Transport**
  - 15 year goal is 120 passenger, Mach 0.6, 1200 nm range
  - Must reduce rotor weight fraction, yet still be aeroelastically stable
  - Candidate rotor system to be selected FY06

- **Bell Helicopter, Textron - V-44 (Quad) Tiltrotor**
  - Feeds into both NASA and Army programs
  - Low cost, low weight rotor

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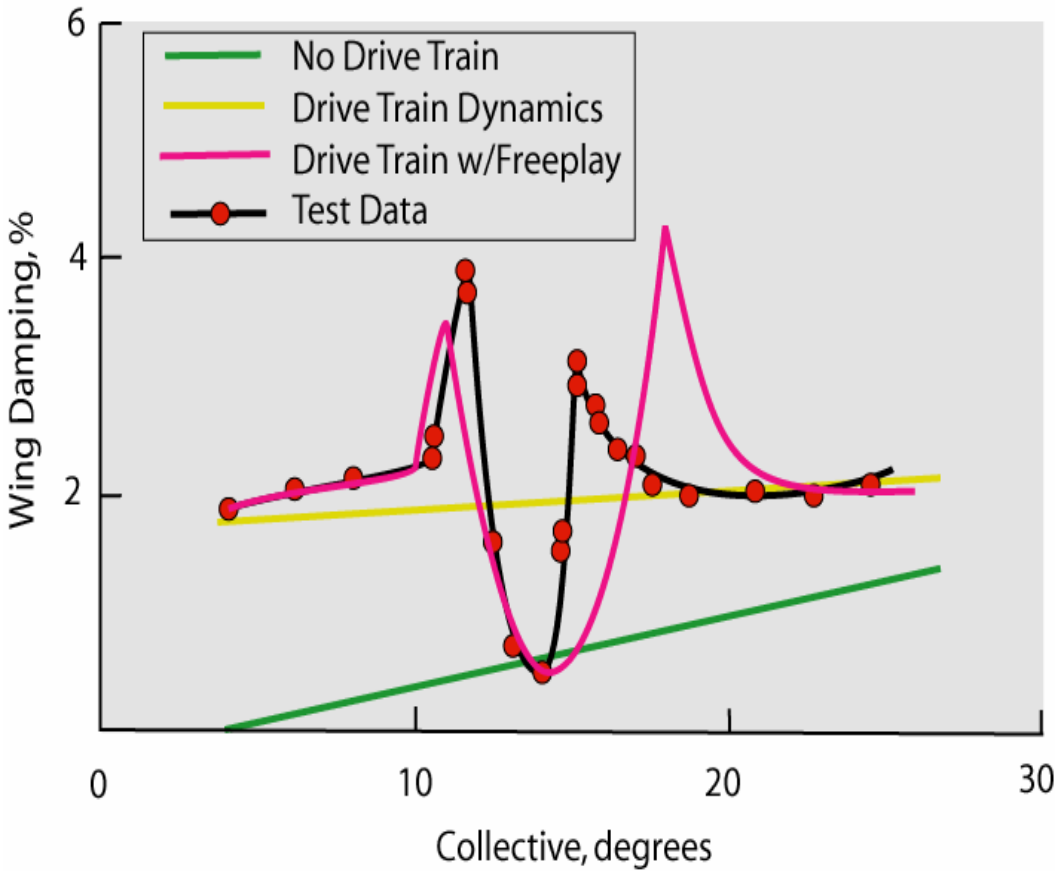
Problem Statement

- **Measure slack angle**
- **Determine source of slack**
- **Suggest methods of reducing slack to help alleviate low damping bucket**



Tests and Results

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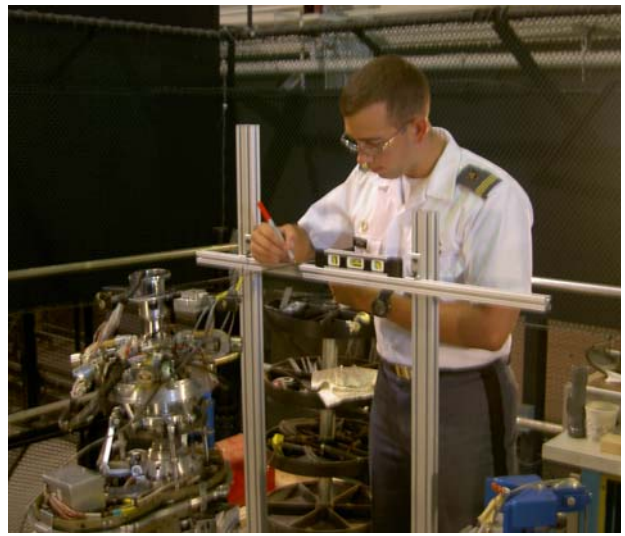
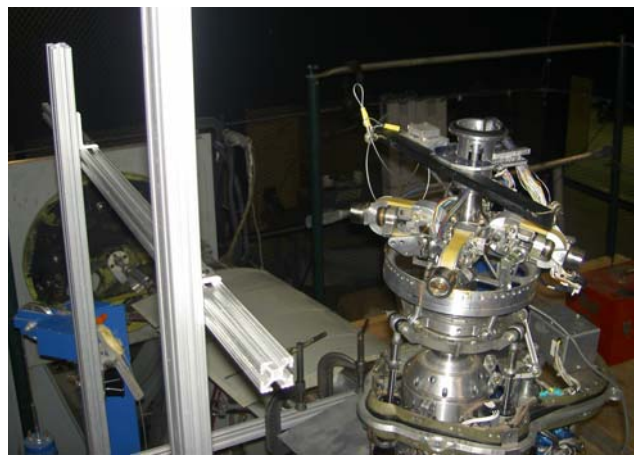
- **Measuring free-play Angle**
  - Theory
    - Used Trigonometry for Triangles
    - $\tan(\theta) = a/b$
  - Tested with the drive shaft fixed and unfixed
  - Conducted the calibration in both airplane and helicopter modes
    - Angle in Airplane mode: 0.78 deg
    - Angle in Helicopter mode: 0.68 deg

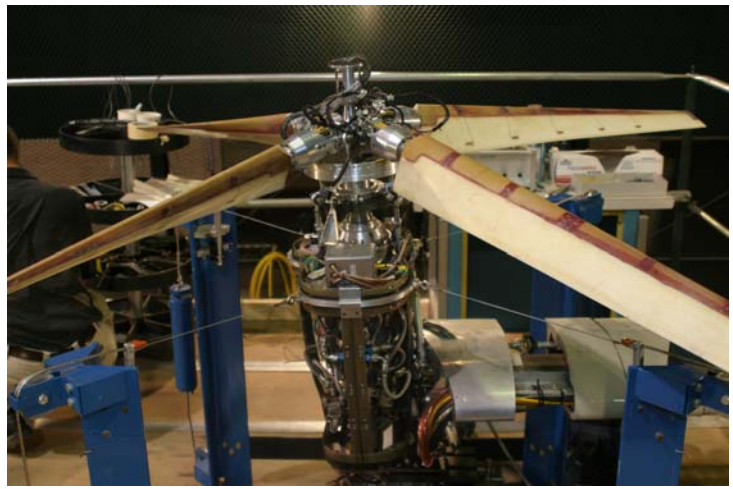




Tests and Results

VEHICLE TECHNOLOGY DIRECTORATE

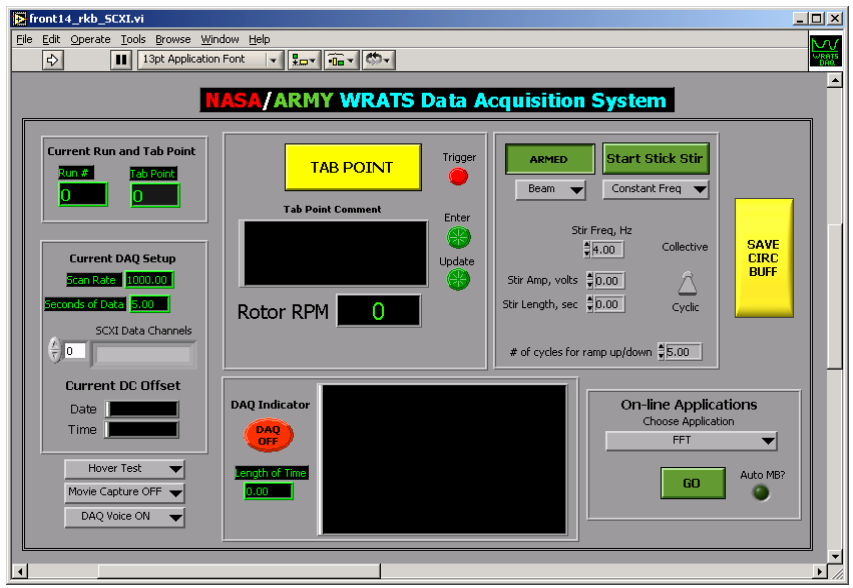
- **Measuring free-play Angle**
  - Results
    - The free-play angle is attributed to slack in the swash plate and the gear box
      - Swash plate adds a degree to the free-play angle
    - The drive shaft is does not contribute to the free play angle
    - It needs to be reduced
  - Use of My Data
    - Improve fidelity of DYMORE model of WRATS
    - Will use DYMORE model to perform parametric study aimed at improving stability characteristics of SASIP rotor



Tests and Results

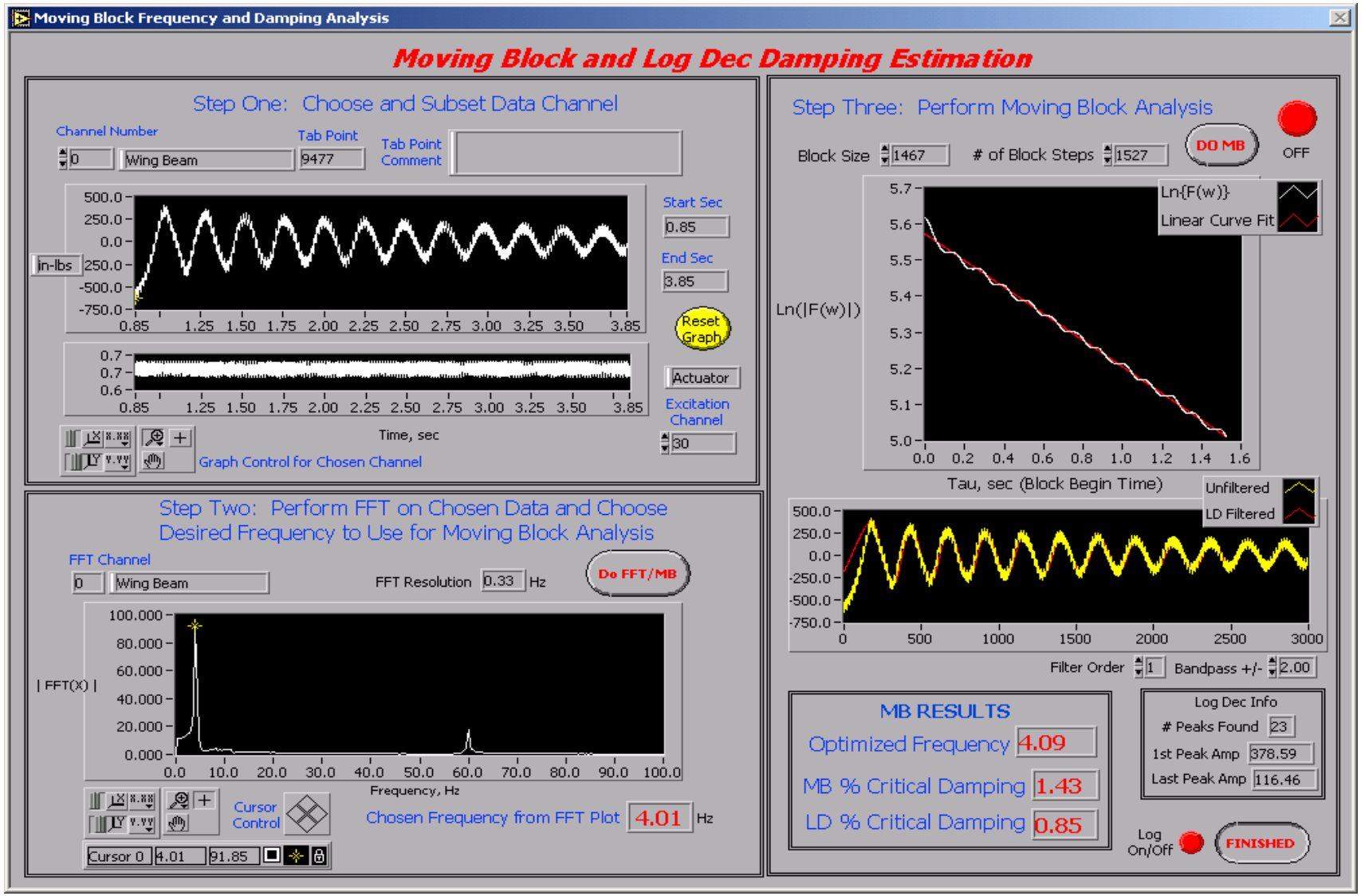
VEHICLE TECHNOLOGY DIRECTORATE

- **Mast Damping**
  - Applied a couple to the shaft
  - Excited mast torsion mode
  - Analyze the time the system takes to dampen out the vibration
    - Used DAQ program written in LabVIEW
  - **Results**
    - At torques >140 in-lbs, the dampening was immeasurable
    - Freq: 4.14-5.14
    - MB % Crit Damp: 1.25-1.4
    - LD % Crit Damp: 0.78-0.95



Test and Results

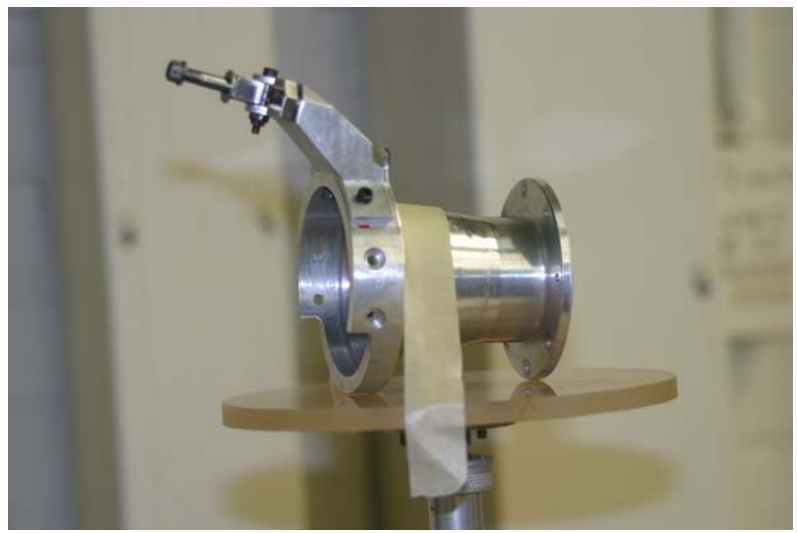
VEHICLE TECHNOLOGY DIRECTORATE



Tests and Results

VEHICLE TECHNOLOGY DIRECTORATE

- **Moment of Inertia**
  - Measured the moment of inertia for each part of the 3 blade stiff inplane hub
    - Used the Moment of Inertia Instrument
    - Data will be used to build a model in DYMORE
  - The model will test some designs that engineers are analyzing for a Tiltrotor UAV



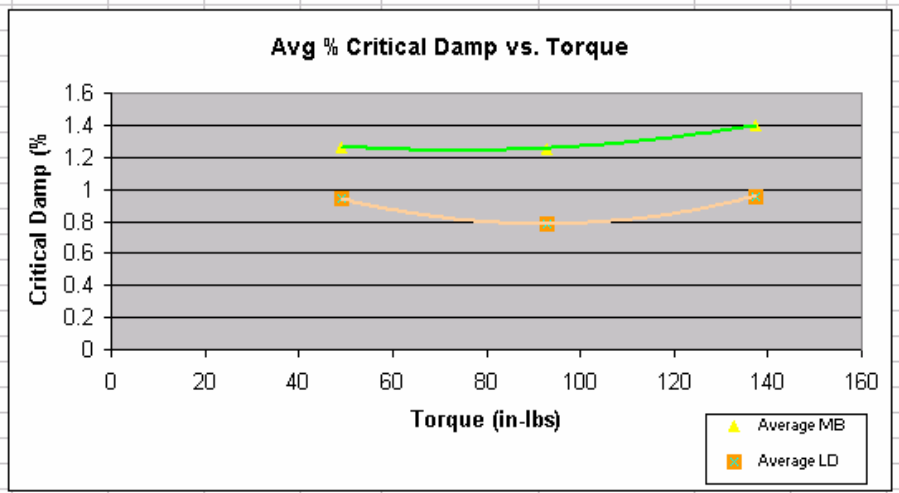
Test and Results

VEHICLE TECHNOLOGY DIRECTORATE

Mast Dampening Data

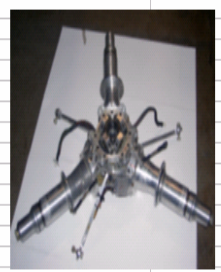
run #	Load	Torque	Freq	MB% Crit Damp	LD% Crit Damp
9463	4	49.7512	5.14	1.46	1.19
9464	4	49.451	5.15	1.19	0.95
9465	4	48.6122	5.16	1.17	0.75
9466	4	48.8358	5.13	1.24	0.87
9467	8	93.6913	4.53	1.28	0.73
9468	8	93.484	4.55	1.24	0.72
9469	8	92.4155	4.58	1.21	1.03
9470	8	92.0249	4.59	1.29	0.65
9471	12	137.645	4.12	1.38	1.11
9472	12	137.125	4.17	1.47	1.17
9473	12	136.903	4.12	1.36	0.81
9474	12	137.375	4.15	1.38	0.74

avg @ 4	49.1625	5.145	1.265	0.94
avg @8	92.9039	4.5625	1.255	0.7825
avg @12	137.262	4.14	1.3975	0.9575

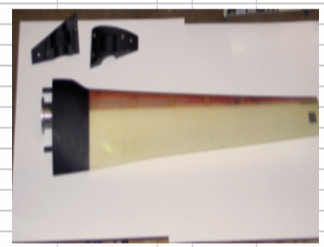


Moment of Inertia Data

Part Name	Weight lb	Weight slug	Mast Location in from CoR	Torsional msec	Inplane msec	Out of Plane msec	Torsional lb-in^2	Inplane lb-in^2	Out of Plane lb-in^2
Stiff in Plane Hub	5.900	0.183	0.000						
Stiff in Plane Hub (disassembled)	3.000	0.093	0.000	1411	1885	1411	30.46	55.53	30.46
Pitch link w/o Bolt	0.050	0.002		309	338	338	0.03	0.33	0.33
Retaining Screw & Nut	0.050	0.002	10.590	307	307	307	0.01	0.01	0.01
Outboard Section	0.150	0.005	9.330	313	318	318	0.07	0.12	0.12
Middle Section	0.200	0.006	6.750	319	327	327	0.13	0.22	0.22
Inboard Section w/ Pitch Arm	0.400	0.012	3.790	400	421	402	1.07	1.35	1.10
Blade Cuff	2.250	0.070	5.340	419	417	346	1.32	1.29	0.42
Blade	0.300	0.009	18.290	607	4467	4500	4.42	318.61	323.35



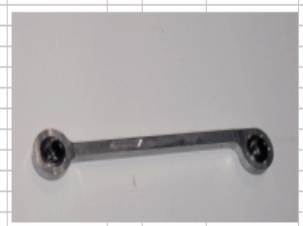
Assembled Hub



Blade and Blade Cuff

Disassembled Hub

Middle & Outboard Sections



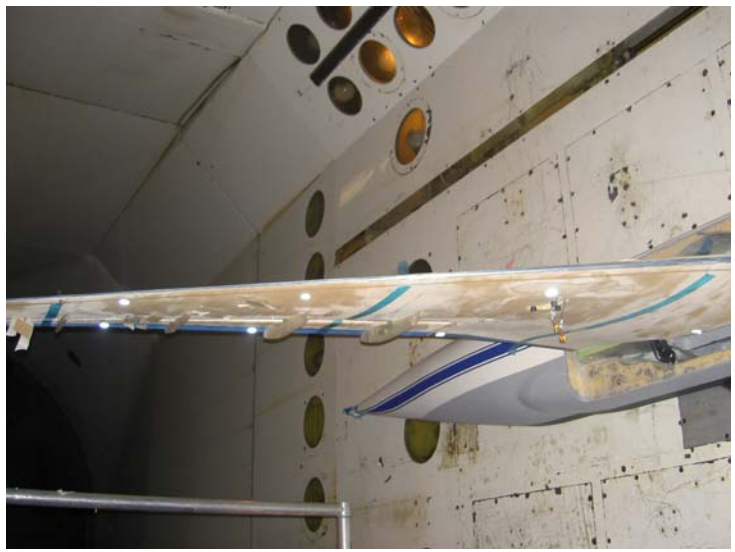
Pitch Link

Inboard Section w/ Pitch Arm

Transonic Tunnel

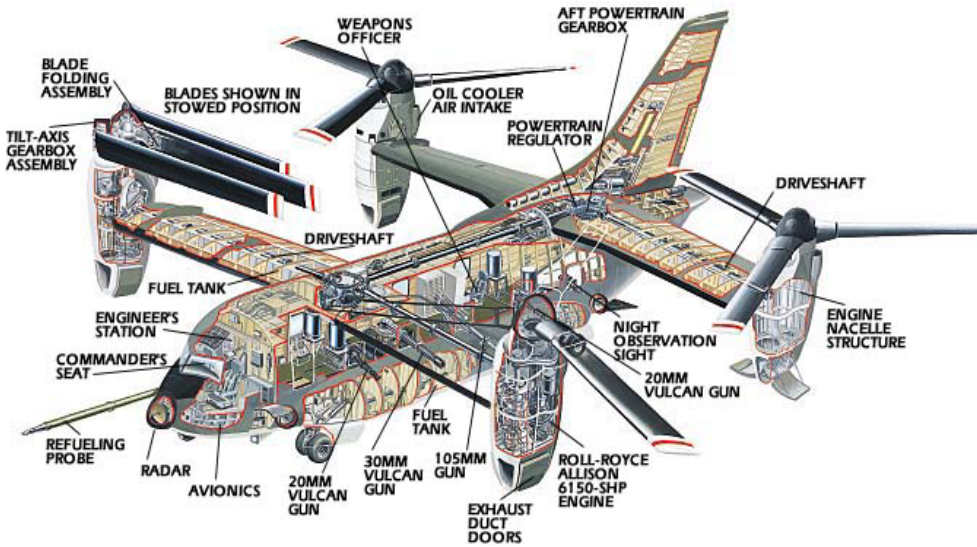
- **Mars ARES**
  - **A**erial **R**egional-scale **E**nvironmental **S**urvey of Mars
  - UAV Scout Plane

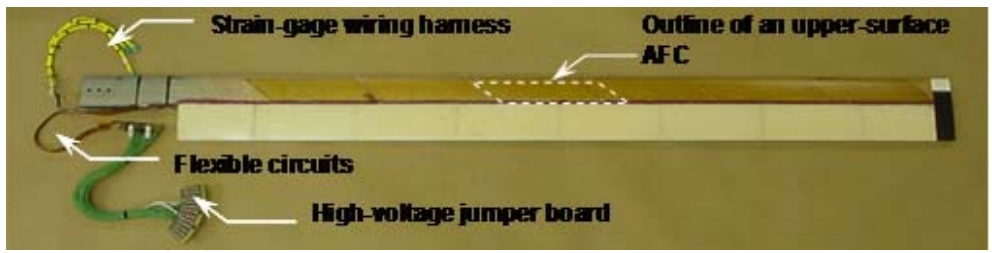
- **High Speed Slotted Wing**
  - Employ a slot along ¾ chord
  - Helps for more stability during high speed flight



Future Areas

- **Tiltrotor Aircraft**
  - 5 or more blade, Soft-inplane hubs
  - 2 Wing, 4 Prop Aircraft
- **Active Twist Blades**
  - Use Piezoelectric materials
  - Current applied to them they expand and contract
  - Used to dampen vibration in the blades
    - Less noise → Stealth
    - Lower blade loads
    - Lower fuselage vibrations





Learning Points

- **Flutter Phenomenon**
- **How Tiltrotor Aircraft Operate and Design Concerns**
- **Piezoelectric Materials & their Future in the Aerospace Field**
- **Multi-Body Dynamics used in Computer Modeling**
  - I-DEAS
  - DYMORE
- **Importance of testing in a Transonic Tunnel**
  - Viewed the Mars Aries UAV Test
  - Viewed the High Speed Slotted Wing Test
- **Working with Civilian Army/NASA Employees**
  - Their research benefits the Army
  - Command Structure
  - Knowledge/ Resources

Special Thanks

ARL

- LTC David Meyer
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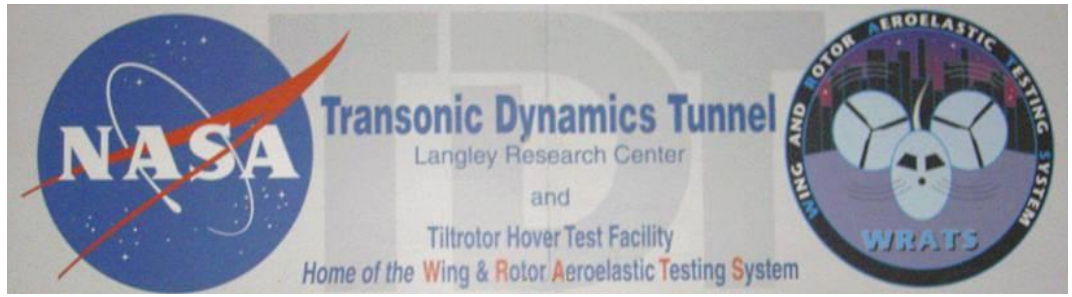
- Jeff Singleton
- Mike Ramsey
- Chester Langston
- Dr. Martin Sekula

NASA

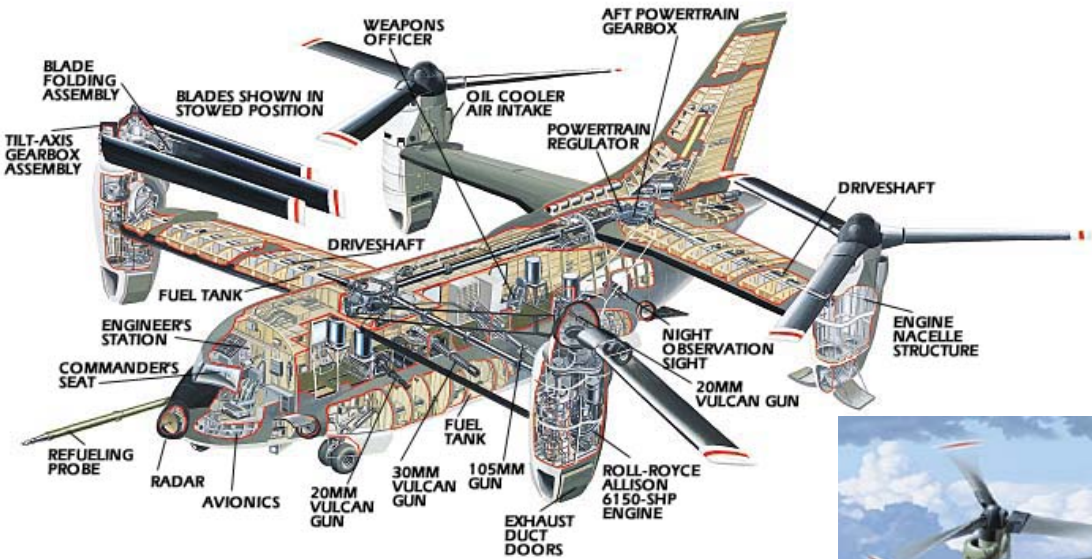
- Dave Piatak
- Tom Ivanko

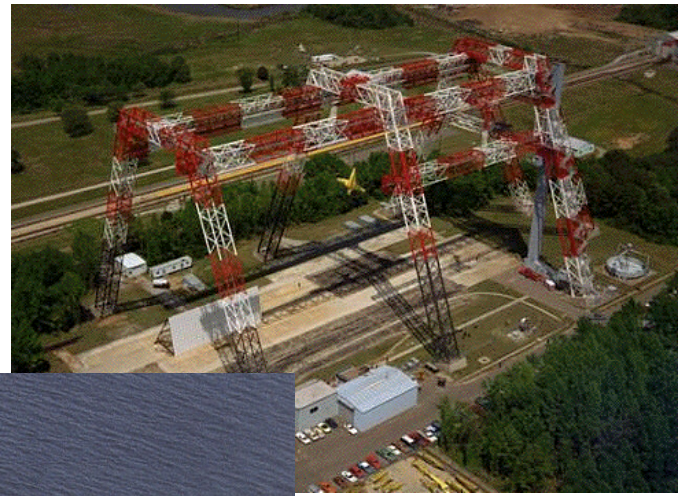


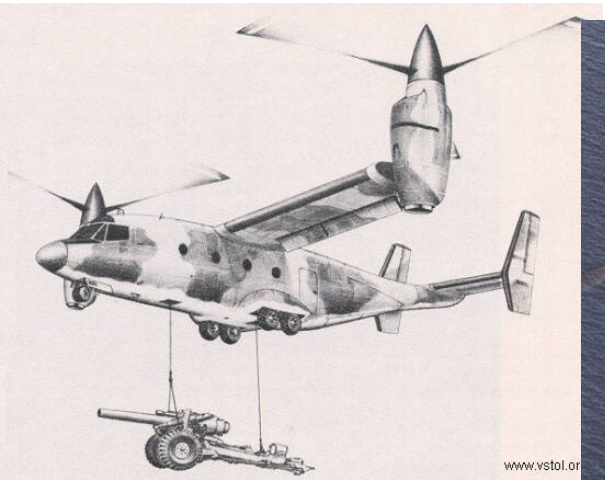
Questions

Bell Textron V-44

Inside The Quad Tiltrotor







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