

# 5 Years Later

*Shades of Blue*

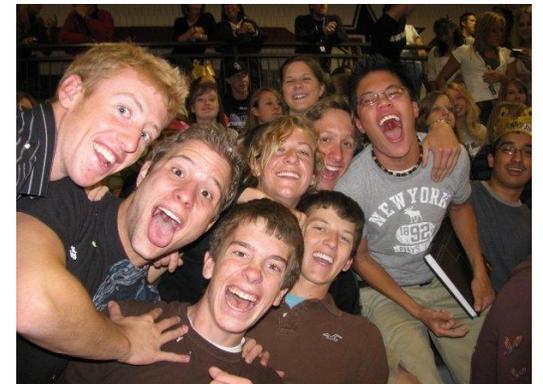
**Andrew Tsoi**

Lockheed Martin Space Systems Company  
University of Colorado Boulder (M.S. 2014)  
Heritage High School (Class of 2008)



# A LITTLE ABOUT ME

- › Born June 11<sup>th</sup> 1990 in Englewood CO
- › K-12 (Littleton Public Schools)
  - Runyon Elementary
  - Powell Middle School
  - Heritage High School
- › Clubs and Activities
  - Littleton Rotary/Interact Club
  - Destination Imagination
  - Club Inline Hockey
  - Varsity Lacrosse
  - Yearbook (Sports Editor)
  - National Honor Society



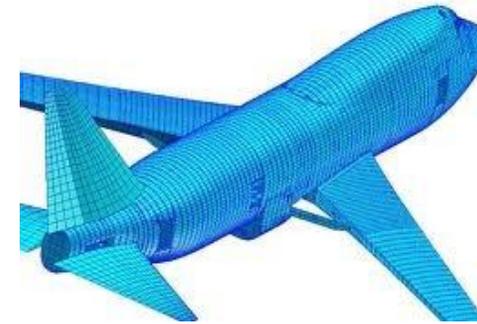
# MR. WARREN

- › Math teacher at Heritage H.S.
  - Advanced Algebra and Calculus
- › Key Lessons
  - “Use your imagination”
  - “Be creative”
  - “Think outside the box”
- › I chose to major in aerospace engineering my senior year



# THE LAST FIVE YEARS

- › University of Colorado at Boulder
- › Bachelors in Aerospace Engineering Sciences (ASEN) in May 2013
- › Masters in ASEN/Structures and Materials in May 2014
- Clubs and Activities
  - Student Leadership Council
  - Student Success Center
  - Men's Club Lacrosse
  - Zeta Beta Tau Fraternity



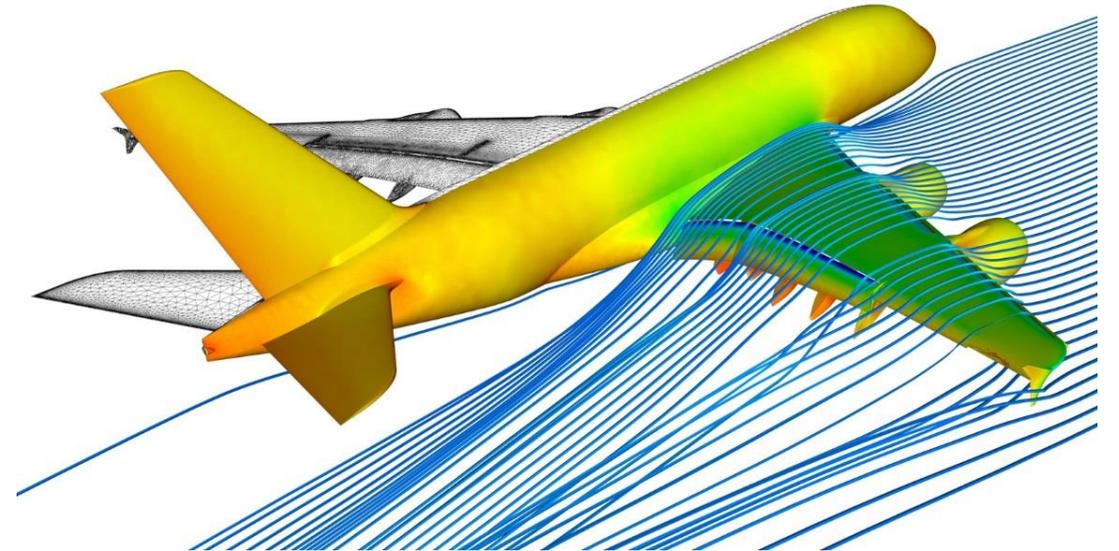
# WHAT IS ENGINEERING?

SCIENCE IS THE **WHAT/WHY**



*Karman vortex sheet:* repeating swirling vortices caused by unsteady separation of flow of a fluid around blunt bodies.

ENGINEERING IS THE **HOW**



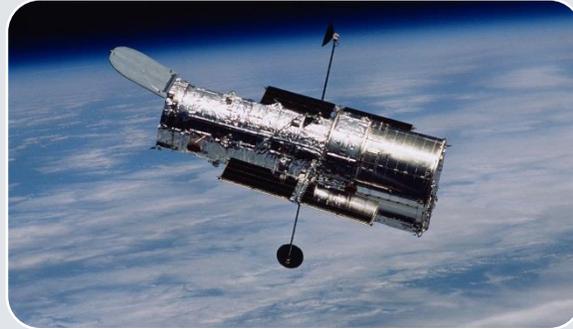
*Boundary layer injection:* injecting fluid into the airstream to create turbulence such that more lift is generated along the wing. More lift means less fuel. Less fuel means more efficient airplanes.

# AEROSPACE ENGINEERING IS A BROAD FIELD



## AERONAUTICS

- Aircraft technologies
- Military and civilian applications
- Aerodynamic sciences



## ASTRODYNAMICS

- Spacecraft technologies
- Ballistics and celestial mechanics
- General relativity



## LAUNCH VEHICLES

- Space Shuttle
- Space Launch System/Orion
- 100+ others

# AEROSPACE ENGINEERING IS A BROAD FIELD



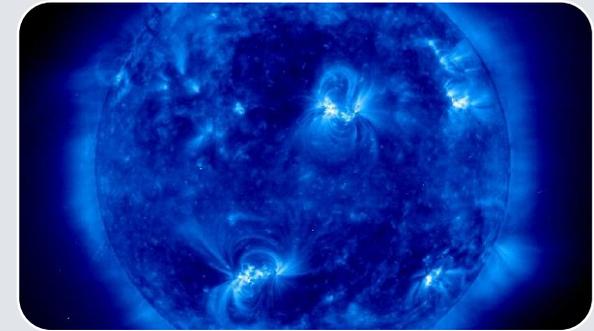
## BIOASTRONAUTICS

- Human spaceflight
- Biological, behavioral and medical space sciences
- Design of payloads, space habitat, and life support systems



## ROBOTICS

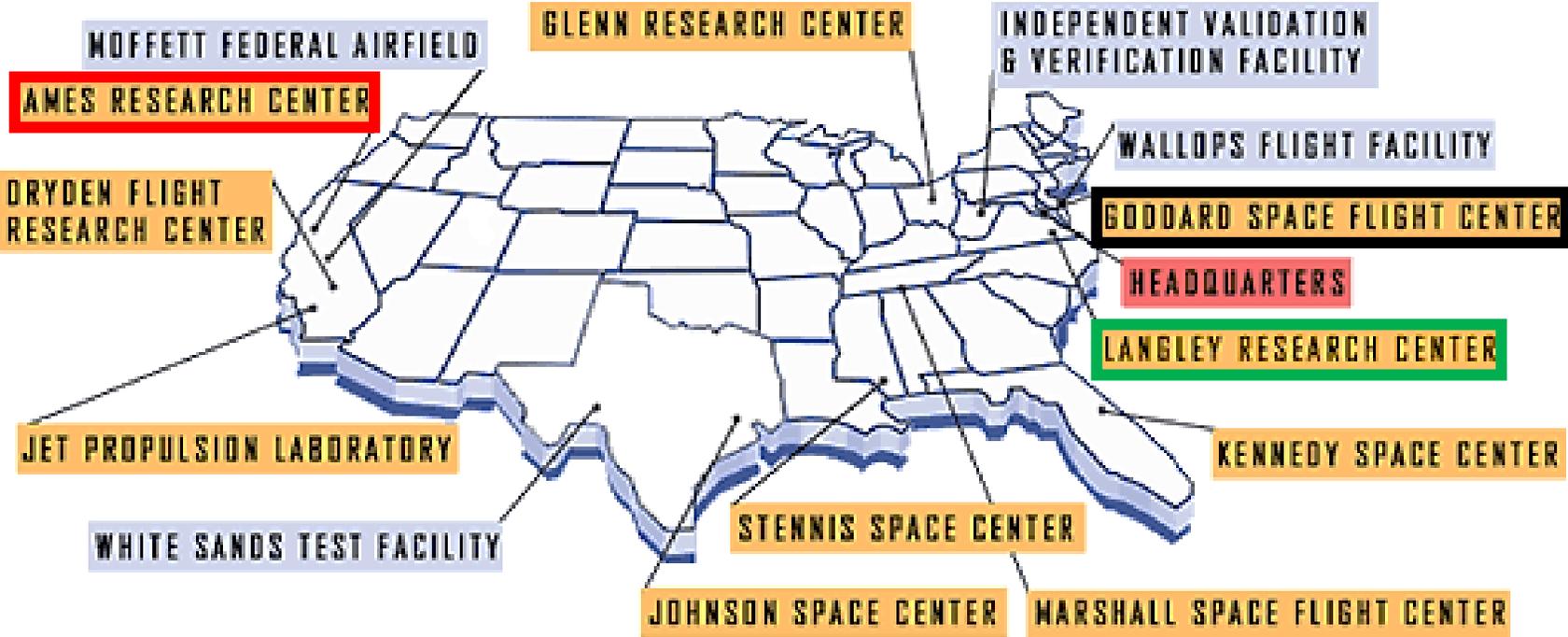
- Planetary exploration (Mars Science Laboratory - Curiosity)
- Autonomous vehicles
- Communication (GPS)



## SPACE PHYSICS

- Heliophysics (sun)
- Earth atmosphere (weather)
- Galactic science

# 10 NASA FIELD CENTERS TO DO THE JOB



LANGLEY



GODDARD



AMES

# THE CALL THAT CHANGED MY LIFE

On Tuesday September 9<sup>th</sup> 2010, I was accepted into the NASA/USRP program.

I would get the opportunity to take an entire year off of school to work at NASA.

I was sitting at my lab station (right) when I got the call. Within a week, I withdrew my from my classes and was on an airplane to NASA Langley!



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# NASA LANGLEY RESEARCH CENTER



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# LANGLEY: MY FIRST ASSIGNMENT

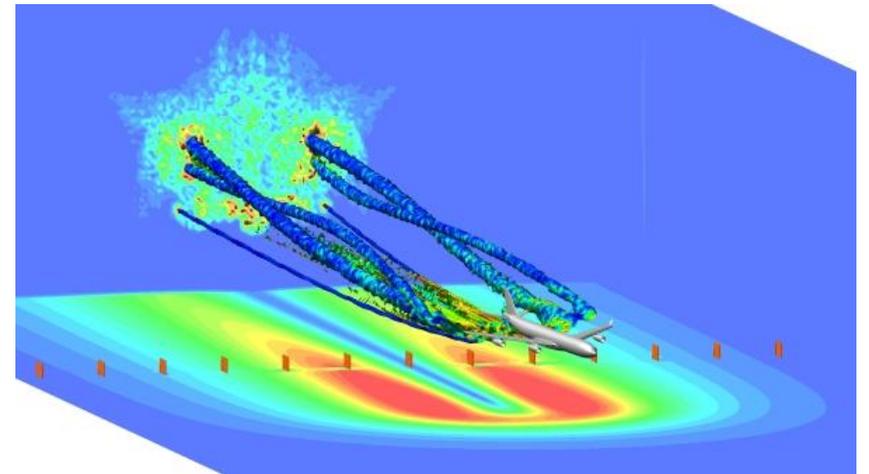
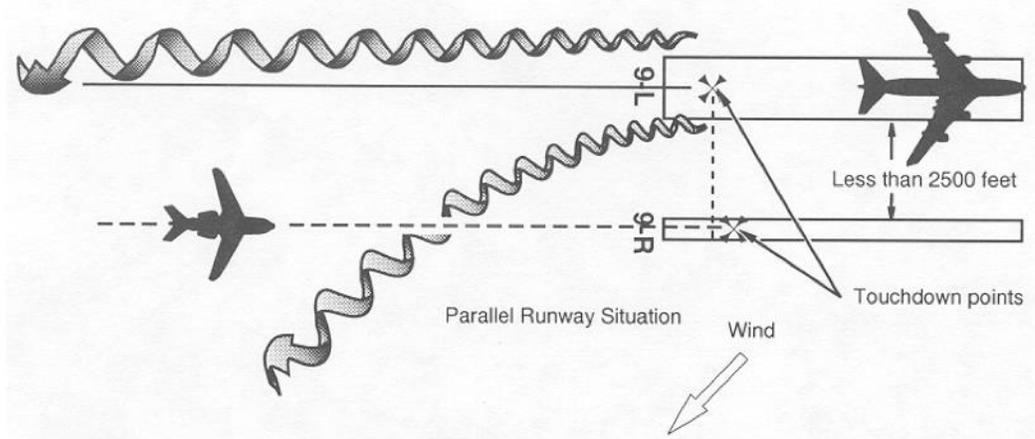
› I studied wake turbulence (white tails)



[http://www.youtube.com/watch?v=\\_\\_pyxPb6gMc](http://www.youtube.com/watch?v=__pyxPb6gMc)

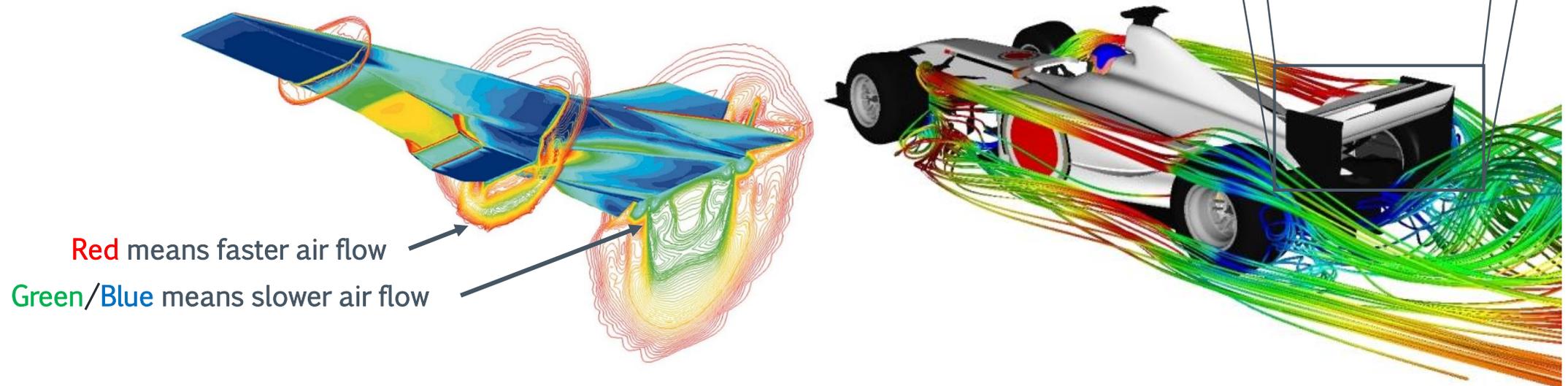
# WAKE TURBULENCE: WHAT DID I DO?

- › Computer models (and lots of it!)
  - Trying to re-create real-life phenomenon with computer models so we can predict and improve existing airplane and airport designs!
  - How far back does the trailing aircraft have to be to avoid wake turbulence?



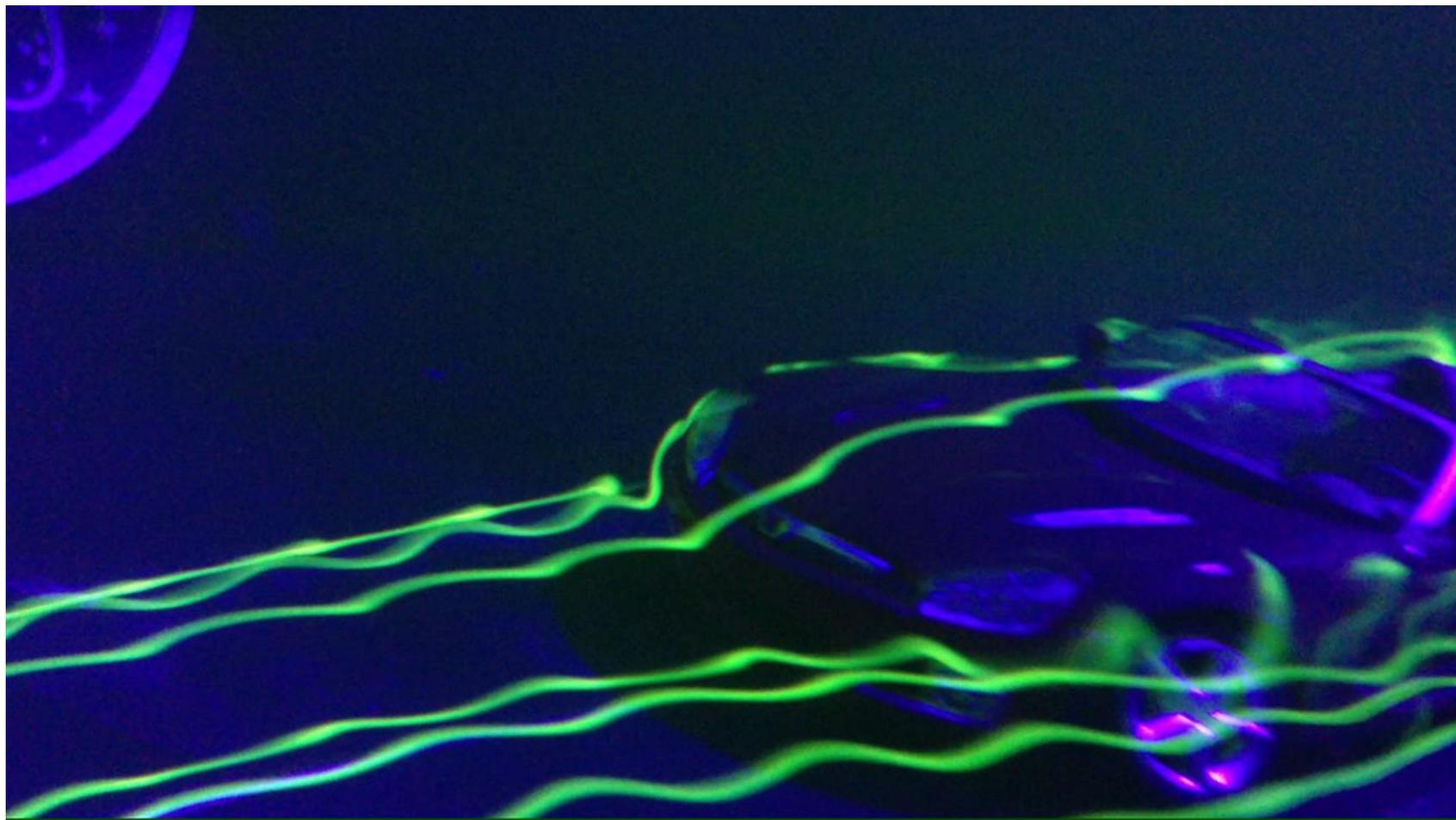
# COMPUTATIONAL FLUID DYNAMICS

- › Using calculus to predict fluid behavior around a body
  - NASA X-43: unmanned hypersonic aircraft
  - Formula One: effectiveness of rear spoilers
- › Allows engineers to predict performance before even building



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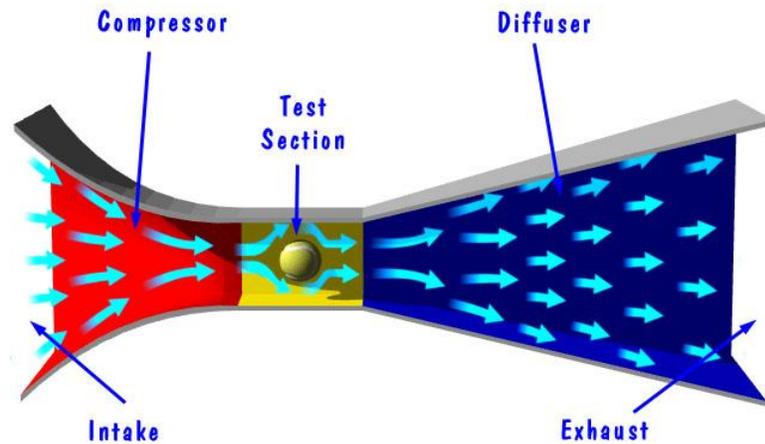
# EXPERIMENTAL VALIDATION



# SUMMER ASSIGNMENT: NATIONAL TRANSONIC FACILITY WIND TUNNEL

## WHAT IS A WIND TUNNEL?

- › A closed or open tunnel where air is blown or pulled around a small test vehicle using fans



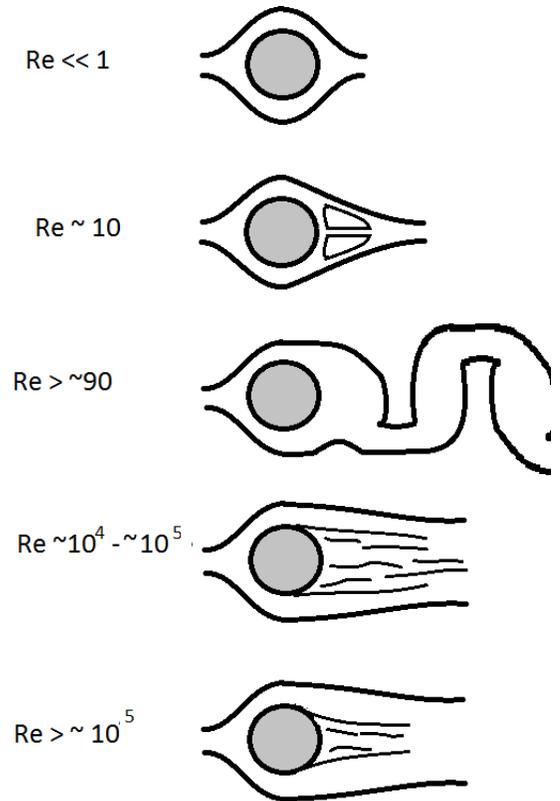
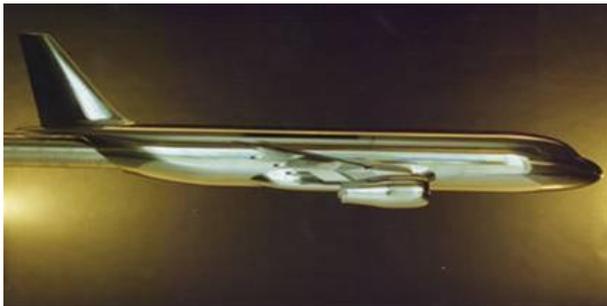
## NATIONAL TRANSONIC FACILITY



# NATIONAL TRANSONIC FACILITY WIND TUNNEL: WHY IS IT IMPORTANT?

NTF CAN MATCH REYNOLDS NUMBERS FOR IDEAL FLIGHT CONDITIONS

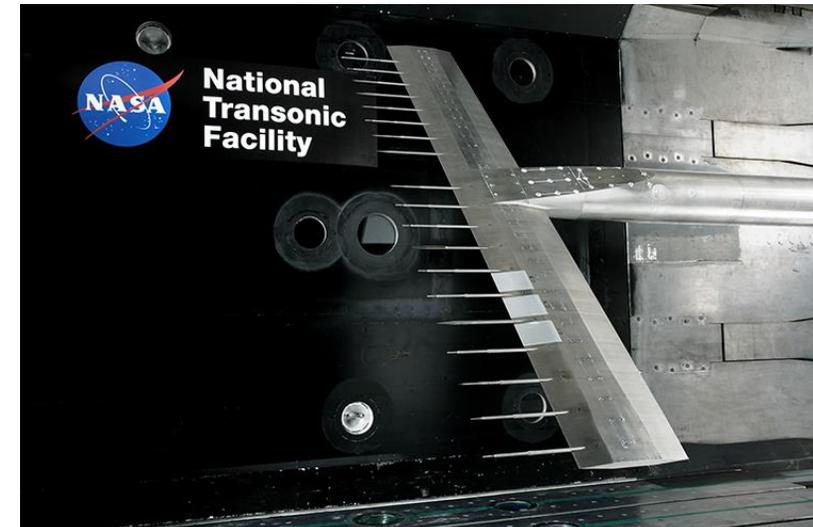
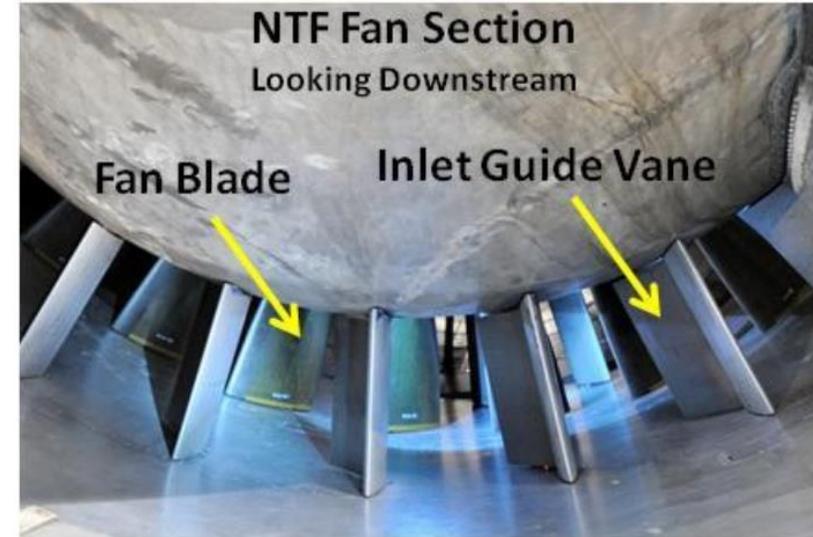
- › When wind-tunnel tests are performed at sea-level, the air is more dense than the ideal cruising altitude the airplane will actually fly at
- › Therefore, the Reynolds number must be changed to meet ideal flight conditions



# SO HOW DO WE CHANGE THE REYNOLDS NUMBER?

## THE ANSWER: CHEMISTRY

- › We inject cryogenic nitrogen (liquid N<sub>2</sub>) into the wind-tunnel to cool down the fuel
- › Temperatures can go as low as - 250<sup>o</sup>F (colder than the surface of Jupiter!)
- › Sensor rake is used to measure temperature, pressure, velocity (crucial to understand turbulence in the test section)



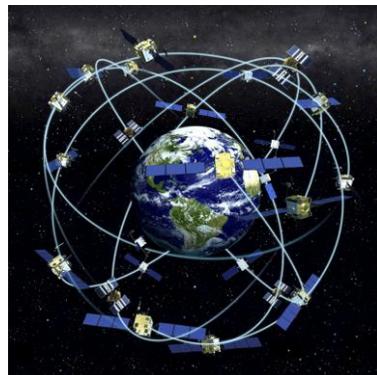
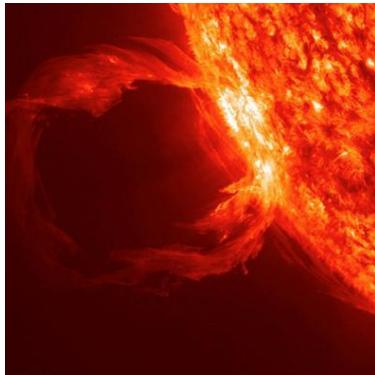
# NEXT SUMMER: NASA GODDARD

- › Came back to CU-Boulder for junior year (2011)
- › Went to Greenbelt MD in May 2012
- › Intern at Mechanical Systems Branch (Code 542)



# NASA GODDARD SPACE FLIGHT CENTER

- › Greenbelt, MD (25 minutes from Washington DC)
- › Spaceflight Research Laboratory
  - Spacecraft (SC) tracking and data acquisition
  - Earth science data information systems (NOAA)
  - Also manages construction of SC systems
- › Space and Atmospheric Sciences (science)
  - Solar system and universe observatory



# THE JAMES WEBB SPACE TELESCOPE

The JWST, NASA's successor to the Hubble Space Telescope, will capture infrared light from the first galaxies. Too large to fit into a rocket fairing, it will unfold in orbit and cool to cryogenic temperatures.

## Primary mirror

6.5 m



The primary mirror is assembled from 18 hexagonal segments.

## Spacecraft bus

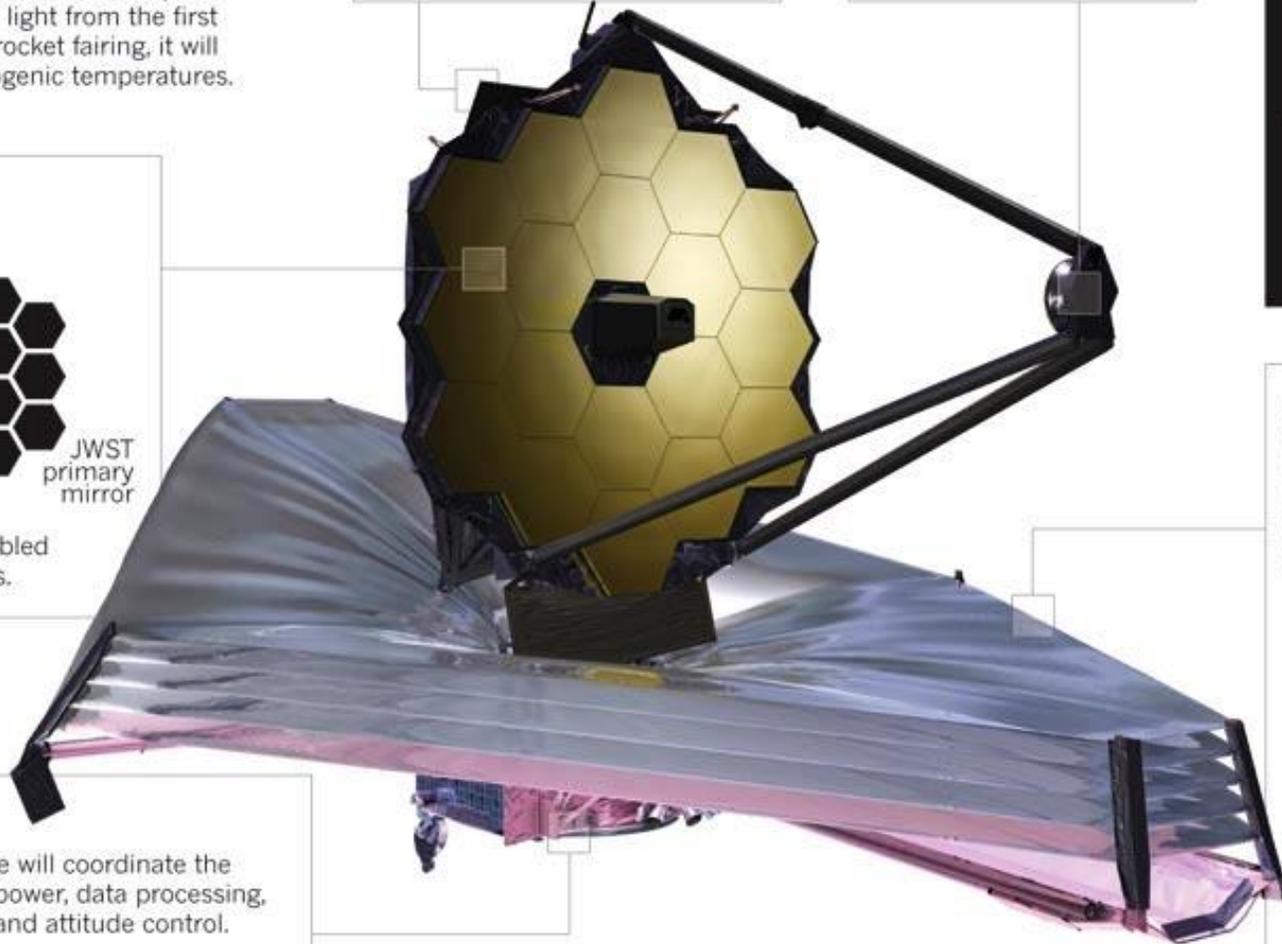
The JWST's command centre will coordinate the mission's communications, power, data processing, propulsion, thermal control and attitude control.

## Backplane

Once the mirror has unfolded, the JWST's 'spine' will hold it still and support the telescope's cameras and spectrographs.

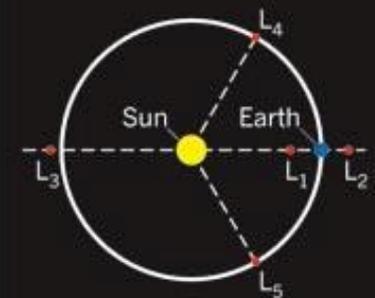
## Secondary mirror

Light will bounce off the primary mirror into the smaller one, then to the instruments.



## LAGRANGIAN POINTS

There are five places where the balance of gravitational forces allows a spacecraft to be stationary relative to the Sun and Earth. The JWST will operate opposite the Sun at the point designated L<sub>2</sub>.



## Sunshield

When deployed in space, the sunshield (right) will be about the size of a tennis court (left). It will protect the telescope from solar heat.

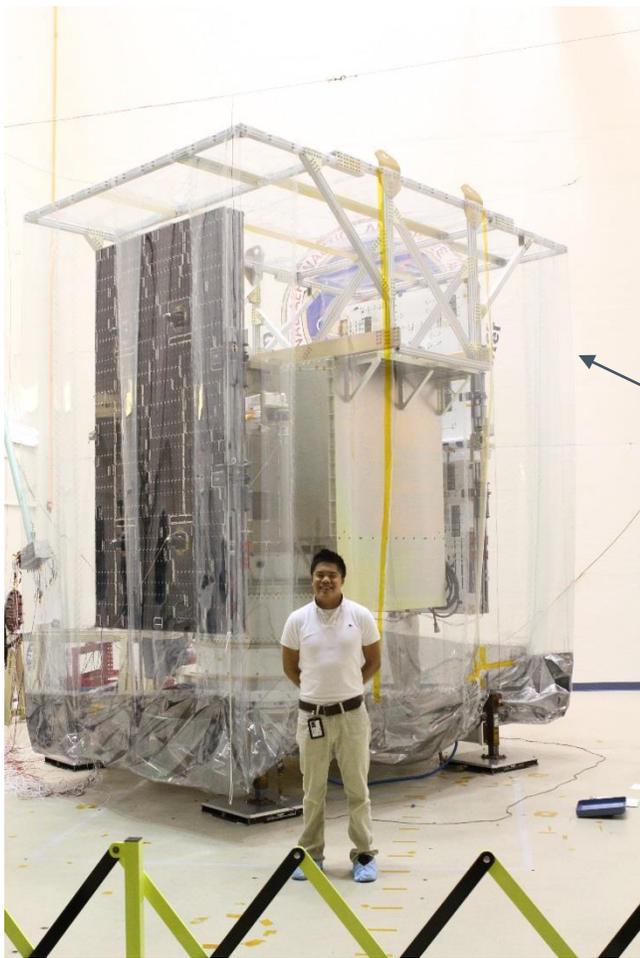


# VIBRO-ACOUSTIC ANALYSIS ON JWST

- › Biggest risk for JWST is breaking during launch
- › JWST's launch vehicle is called the Ariane 5
  - It's freaking loud (170 dB)
  - Death of hearing tissue at 180 dB
- › The sound field of the rocket engine can create lots of problems:
  - Rocket fairing noise transmission
  - Satellite structural/bus failures
  - Satellite instrument failures
- › My job: **Build a better understanding of the structural properties of the satellite.**



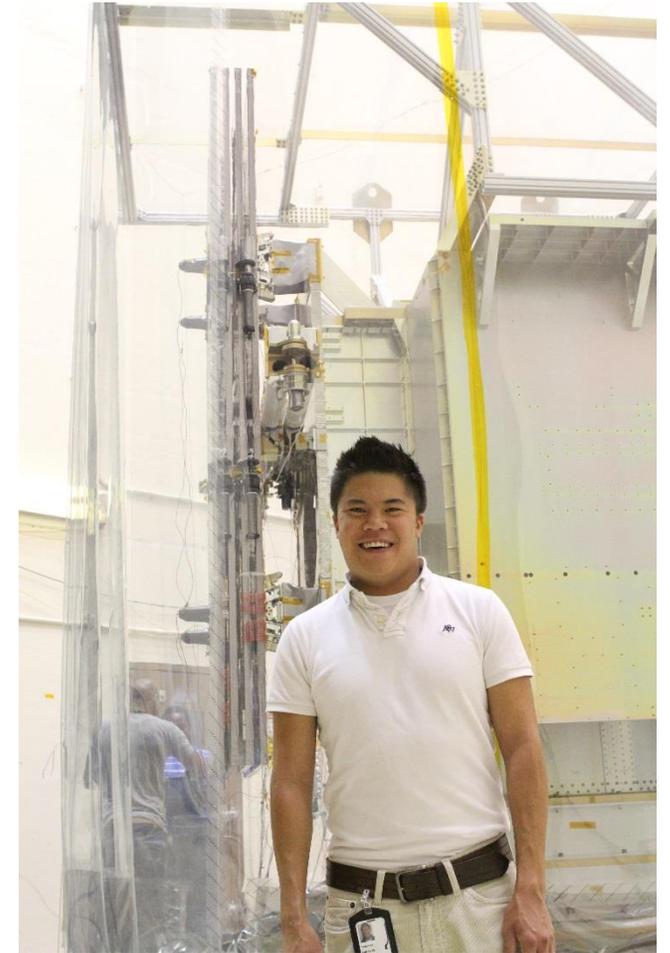
# ACOUSTIC TESTING (~170 dB!)



Sound is an acoustic wave.  
Air pressure can carry debris.

Engineers protect the satellite  
by putting a “tent” over the  
satellite to prevent dust from  
damaging the satellite during  
testing

Because the tent can  
“dampen” the sound, they  
have to crank the sound even  
louder. Crank it up!



# ERN CONFERENCE IN STEM 2013

I had the privilege to present my work at a conference in Washington DC

There, I got meet Leland Melvin (NFL astronaut), Sylvester Gates (physicist) on string theory



**Analysis of MMS and JWST using Finite Element Modeling (FEM)**

**Student Name and University**  
Andrew K. L. Tsai - University of Colorado at Boulder

**Mentor Name and Directorate**  
Ben H. Emory - NASA Goddard Space Flight Center

**Procedure**

ELEMENTS | BOUNDARY CONDITIONS | LOADS | MATERIAL PROPERTIES

MSC NASTRAN (2008 r1)

Natural Frequencies and Mode Shapes

NASTRAN takes multiple input cards that describe the structure's various elements, boundary conditions, material properties, and applied loads. A Lanczos solver computes the real eigenvalues and eigenvectors of the stiffness matrix. In short, the FEA model then outputs the structure's natural frequencies, generalized stiffness, and maximum displacement values.

NASTRAN allows the user to call in use different elements to construct an FEA model that utilizes the correct structural properties and dynamics of the original structure. For MMS, certain composite materials, such as the honeycomb panels depicted above, can be represented as a single one-layer rather than its true two-layer and honeycomb element. The simplification of multiple shell elements is done using the PSHLL card.

The MMS model also utilizes elements to represent joint fixtures that describe the interaction between shells and/or solids. The commonly used elements in the MMS FEA model include the generalized spring-and-damper structural elements (CBUSH) and elastic spring connected elements (CELAS). These elements contain information about the degrees of freedom (DOF) and their respective stiffnesses.

**PSHELL Element Property Translation**

A key example of element integration done last summer is the transformation of PSHLL elements in the MMS model to Salinas elements. This process defines the interlaminar, bending, transverse shear, and coupling properties of thin-shell elements. The PSHLL card defines the structural properties of a honeycomb panel, which are translated into Salinas and MMS input cards.

For example, the cross-sectional moment of inertia (I) can be translated into the appropriate MMS input cards.

**NASTRAN Input**  
Creating the PSHLL card for Honeycomb Panels

Outer Layer (Faceheets)  
Material - reference MAT ID  
Thickness - total thickness  
Fiber orientation - degree  
Inner Layer (Honeycomb Core)  
Material - reference MAT ID  
Thickness - total thickness  
Fiber orientation - degree  
Etc.

MID1, T - in plane load (faceheet) and total thickness  
MID2, 1/2IT1 - bending load (honeycomb) and inertia  
MID3, T/IT - shear load (honeycomb) and shear thickness

**MMS Modal Analysis**

Post-Column		Honeycomb	
Natural Frequency (Hz)	Percent Difference	NASTRAN	MMS
141.037	0.182	141.037	141.037
224.184	0.000	224.184	224.184
264.944	0.434	264.944	264.944
333.056	0.000	333.056	333.056
393.037	0.000	393.037	393.037
453.037	0.000	453.037	453.037
513.037	0.000	513.037	513.037
573.037	0.000	573.037	573.037
633.037	0.000	633.037	633.037
693.037	0.000	693.037	693.037
753.037	0.000	753.037	753.037
813.037	0.000	813.037	813.037
873.037	0.000	873.037	873.037
933.037	0.000	933.037	933.037
993.037	0.000	993.037	993.037
1053.037	0.000	1053.037	1053.037
1113.037	0.000	1113.037	1113.037
1173.037	0.000	1173.037	1173.037
1233.037	0.000	1233.037	1233.037
1293.037	0.000	1293.037	1293.037
1353.037	0.000	1353.037	1353.037
1413.037	0.000	1413.037	1413.037
1473.037	0.000	1473.037	1473.037
1533.037	0.000	1533.037	1533.037
1593.037	0.000	1593.037	1593.037
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1893.037	0.000	1893.037	1893.037
1953.037	0.000	1953.037	1953.037
2013.037	0.000	2013.037	2013.037
2073.037	0.000	2073.037	2073.037
2133.037	0.000	2133.037	2133.037
2193.037	0.000	2193.037	2193.037
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9873.037	0.000	9873.037	9873.037
9933.037	0.000	9933.037	9933.037
9993.037	0.000	9993.037	9993.037

Computes mode shapes and natural frequencies

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# LAST SUMMER: NASA AMES



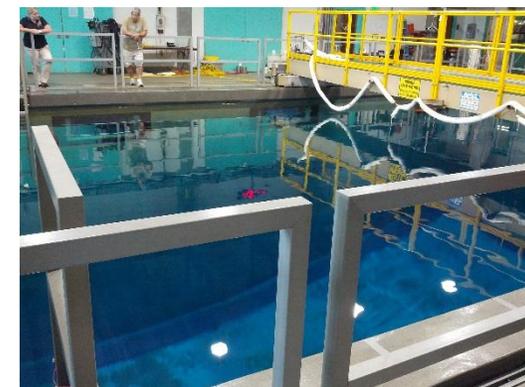
# NASA ACADEMY

- › Premiere leadership development and training program for students
- › Wore a tie almost everyday and interacted with NASA management (the guys calling the shots)
- › Still worked on a individual project and a group project



# INDUSTRY TOURS AROUND THE AREA

- › Company tours to:
  - SpaceX (LA) and Tesla
  - Google
  - Lockheed Martin
  - Boeing Space Systems
  - Monterey Bay Research Institute and Aquarium
  - Lick Observatory
  - Jet Propulsion Laboratory
  - Skybox Imaging
  - Digital Solid State Propulsion
  - Space Systems Loral



# NASA AMES RESPONSIBILITIES

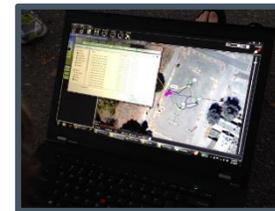
## INDIVIDUAL RESEARCH: AEROELASTIC MODELING

- › Computer models used to predict wing vibration due to turbulence



## GROUP PROJECT: ROTORCRAFT APPLICATIONS

- › Used autonomous quadcopters to demonstrate feasibility of public transportation using quadcopter vehicles



# FINAL PRESENTATION

We gave our final presentation to Code Aeronautics on our second to last day in August

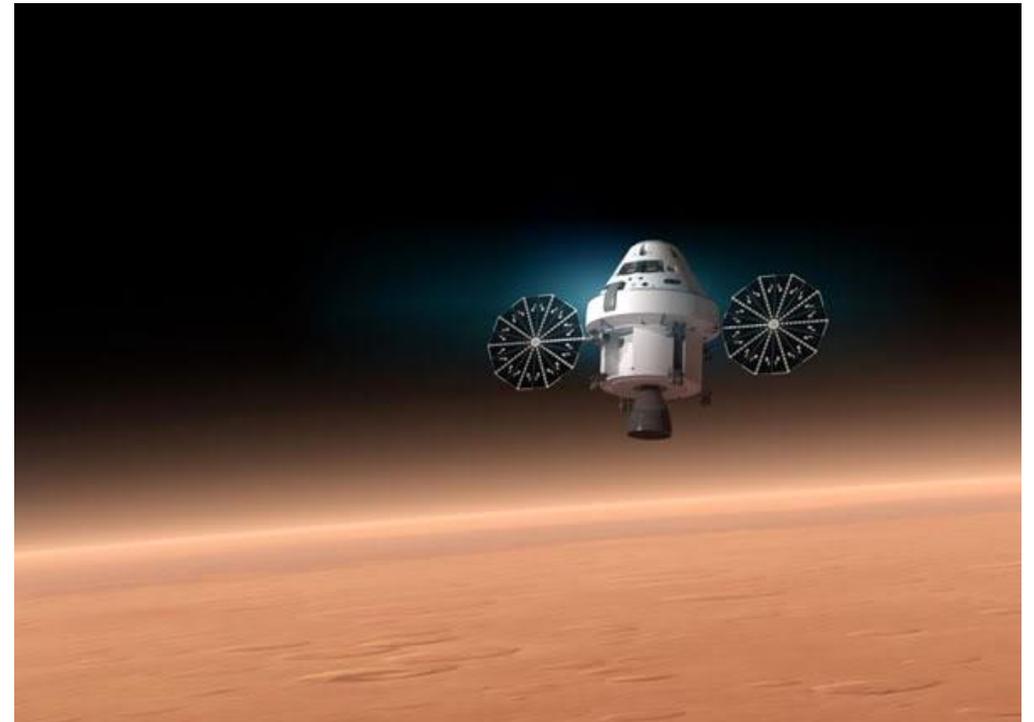
It extremely nerve-racking. Among the audience, included the center director, code-A chief engineer, and more (big named guys).

It was different being the expert in the room.



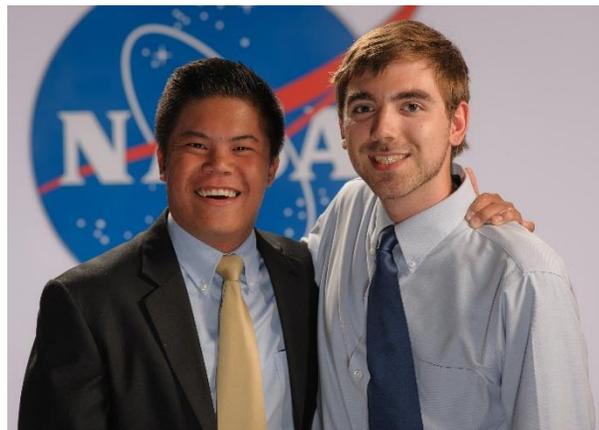
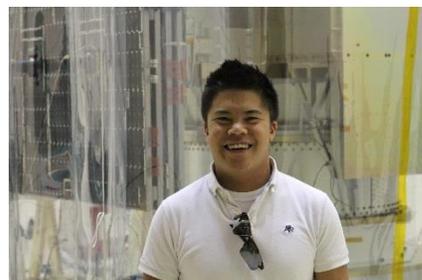
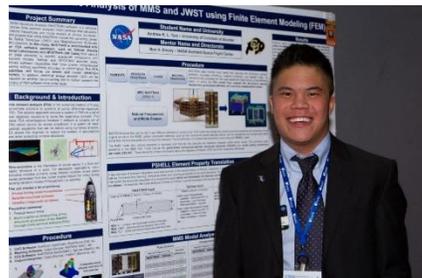
# NOW: LOCKHEED MARTIN - ORION

- › Flight Software Engineering
- › Fault Management: deals with detection, isolation, and recovery (FDIR) of malfunctions onboard the vehicle
- › Systems Engineering: requires broad understand of various subsystems of the spacecraft (propulsion, power, communication, etc.)



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# POST REFLECTION AND COMMENTS



## LESSONS LEARNED

- › Don't be afraid of difficult challenges – face them!
- › You don't need to be smart to be an aerospace engineer, you just need HARD WORK.
- › Strive to be better than you were yesterday, but don't compare yourself with the people around you. Only you can be the judge of yourself.
- › Work hard, but have fun doing it.
- › Be proud of what you do.

# THANK YOU

- › **Andrew Tsoi**  
Orion Flight Software Engineer  
Lockheed Martin Space Systems  
  
University of Colorado Boulder  
ASEN, AESys: BS/MS 2014  
  
NASA Student Ambassador  
Cohort IV: LaRC, GSFC, ARC



# GET INSPIRED

- › Neil deGrasse Tyson

- <http://www.youtube.com/watch?v=9D05ej8u-gU>

- › CU Engineering

- <http://www.youtube.com/watch?v=Q7Y6iH5Oank>

- <https://www.youtube.com/watch?v=0FJhWTa4S9E>

- › A380 Flutter Tests

- <http://www.youtube.com/watch?v=ImSuZjvkATw>