

# 5 Years Later

*Shades of Blue*

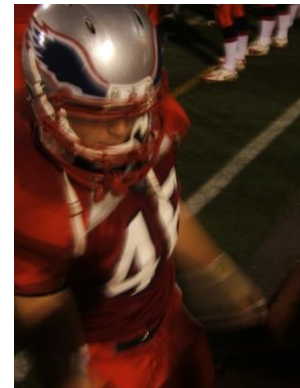
**Andrew Tsoi**

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

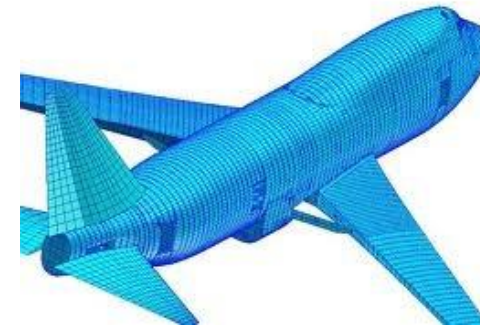
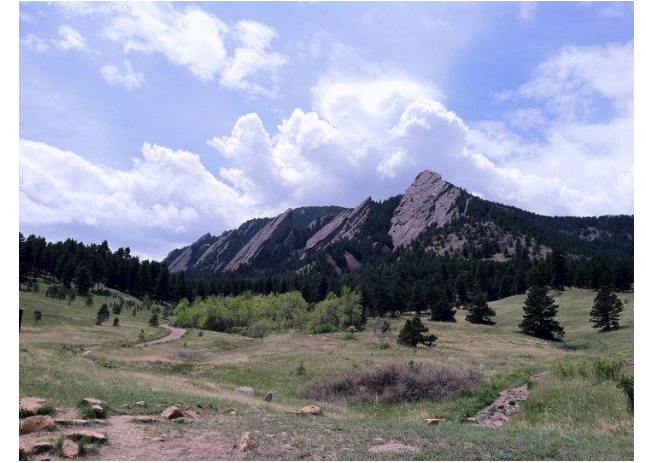
- › Math teacher at Heritage H.S.
  - Advanced Algebra and Calculus
- › Key Lessons
  - “Use your imagination”
  - “Be creative”
  - “Think outside the box”
- › I chose to major in aerospace engineering my senior year





# 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



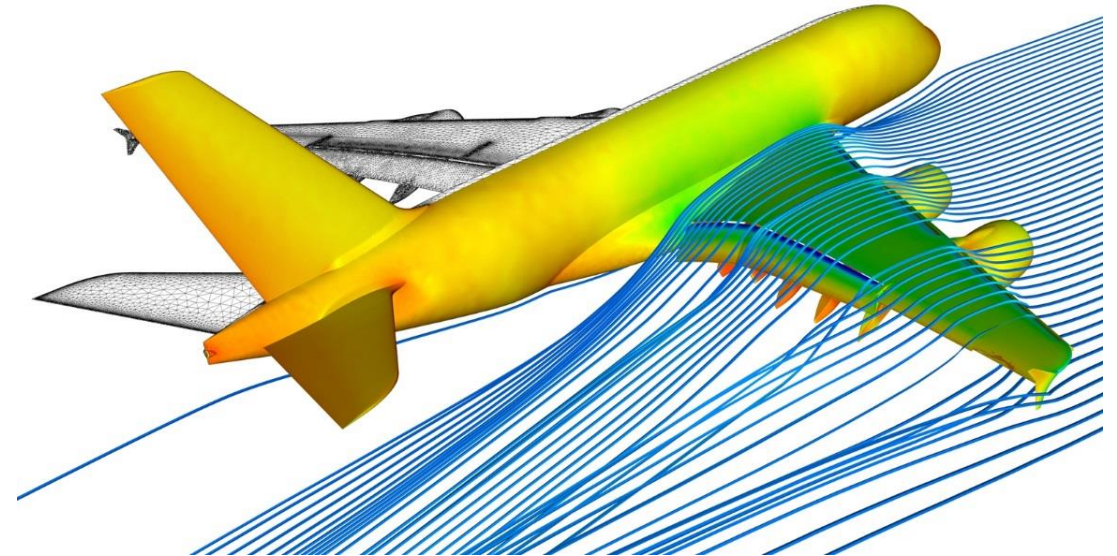
# WHAT IS ENGINEERING?

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.



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# 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

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# AEROSPACE ENGINEERING IS A BROAD FIELD



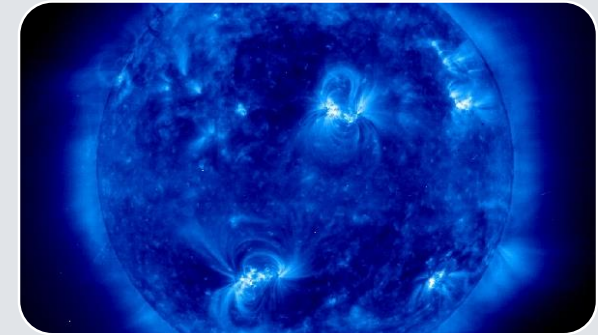
## BIOASTRONAUTICS

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



## ROBOTICS

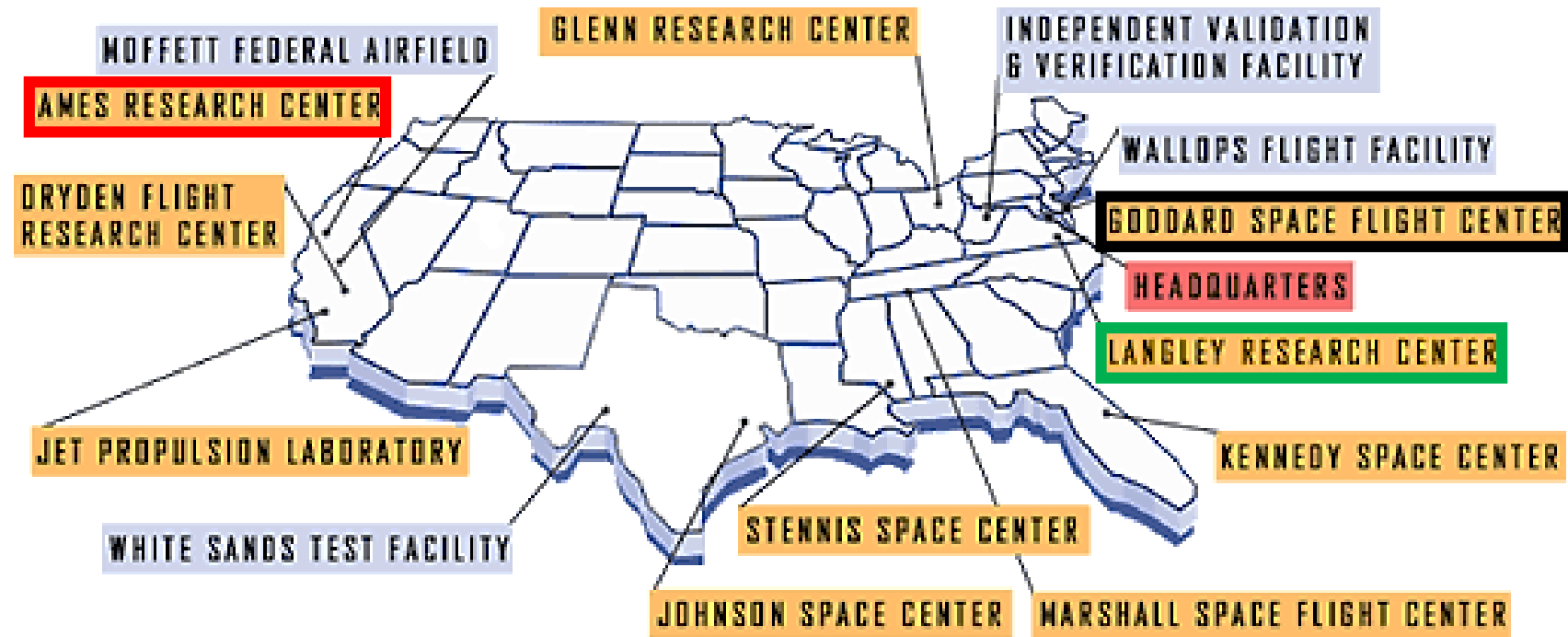
- Planetary exploration (Mars Science Laboratory - Curiosity)
- Autonomous vehicles
- Communication (GPS)



## SPACE PHYSICS

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

# 10 NASA FIELD CENTERS TO DO THE JOB



LANGLEY



GODDARD



AMES

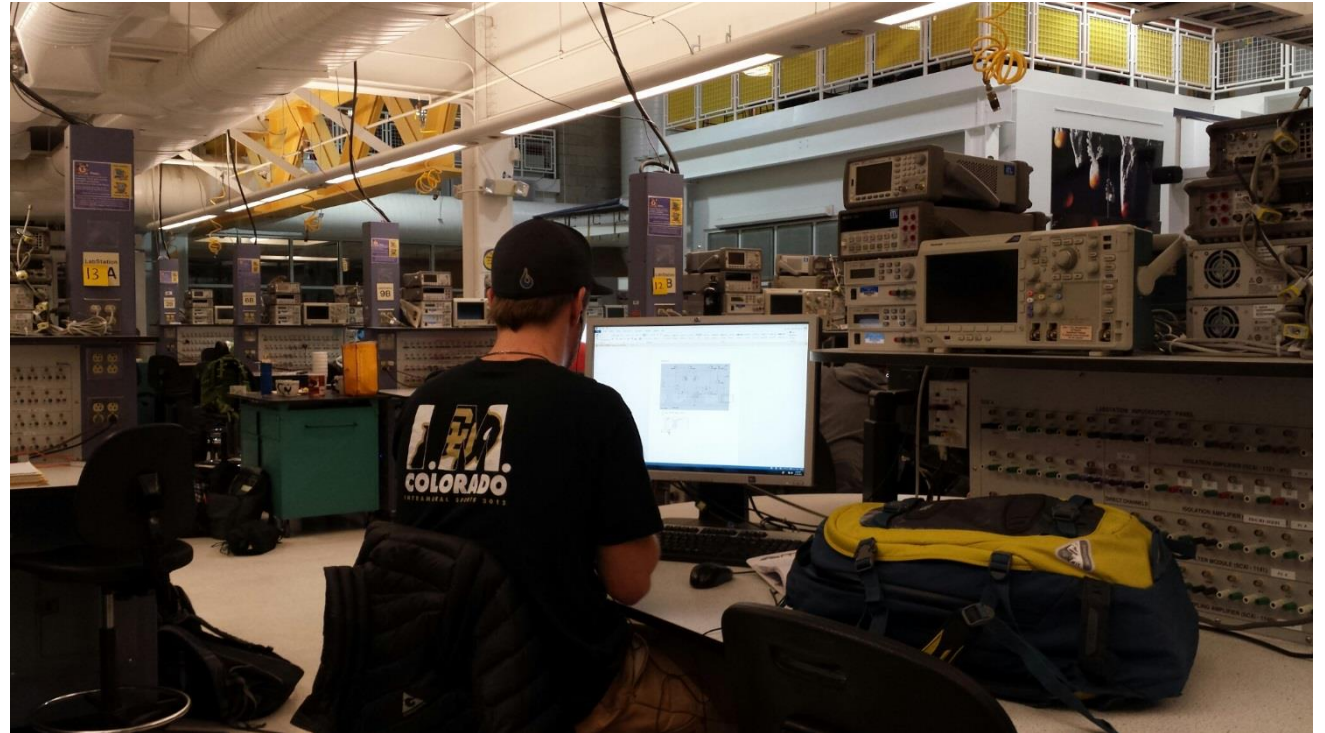


# THE CALL THAT CHANGED MY LIFE

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.

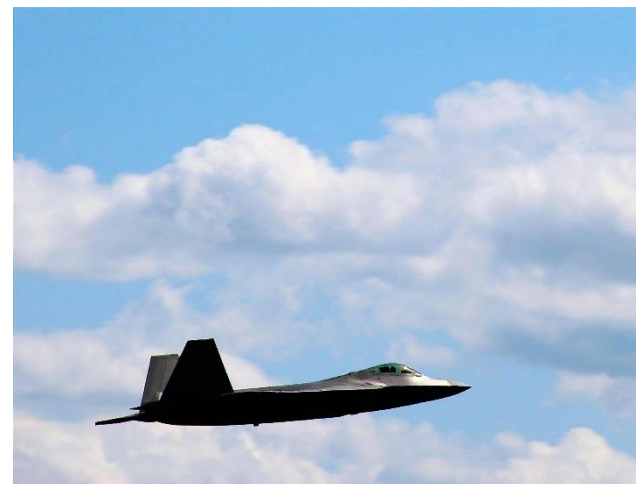
I was sitting at my lab station (right) when I got the call. Within a week, I withdrew my from my classes and was on an airplane to NASA Langley!





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# NASA LANGLEY RESEARCH CENTER



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# LANGLEY: MY FIRST ASSIGNMENT

› I studied wake turbulence (white tails)

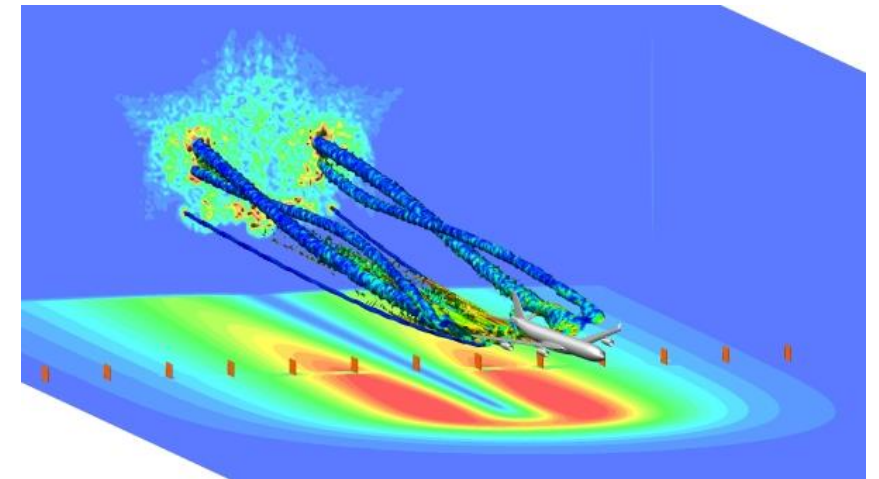
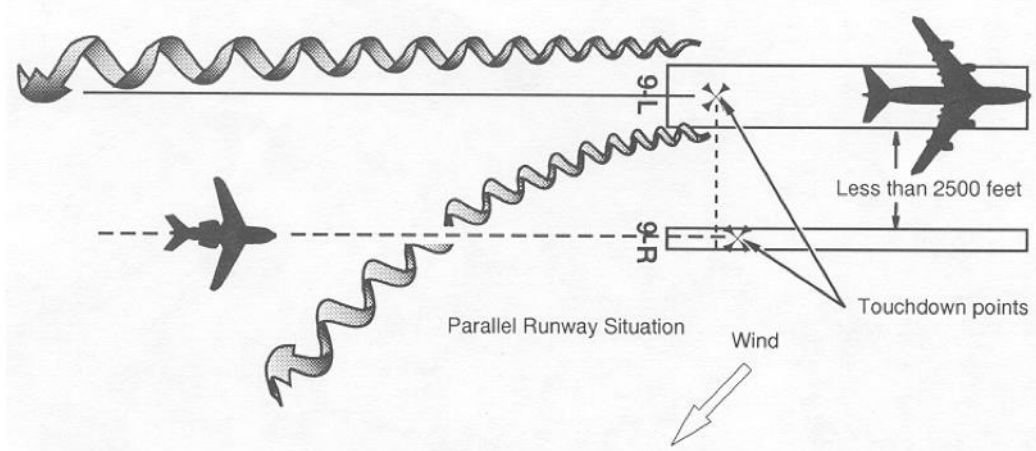


[http://www.youtube.com/watch?v=\\_\\_pyxPb6gMc](http://www.youtube.com/watch?v=__pyxPb6gMc)



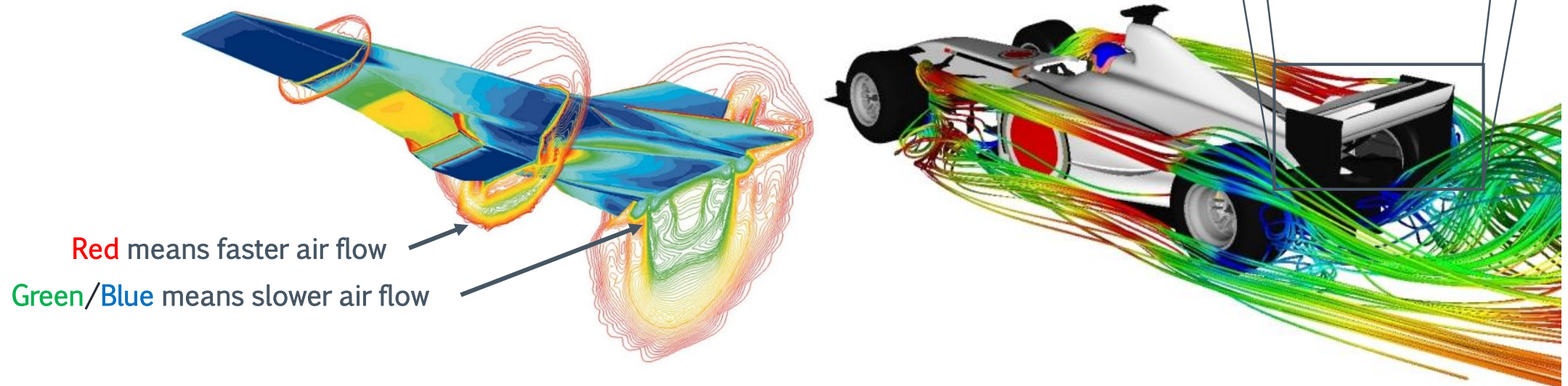
# WAKE TURBULENCE: WHAT DID I DO?

- › 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?



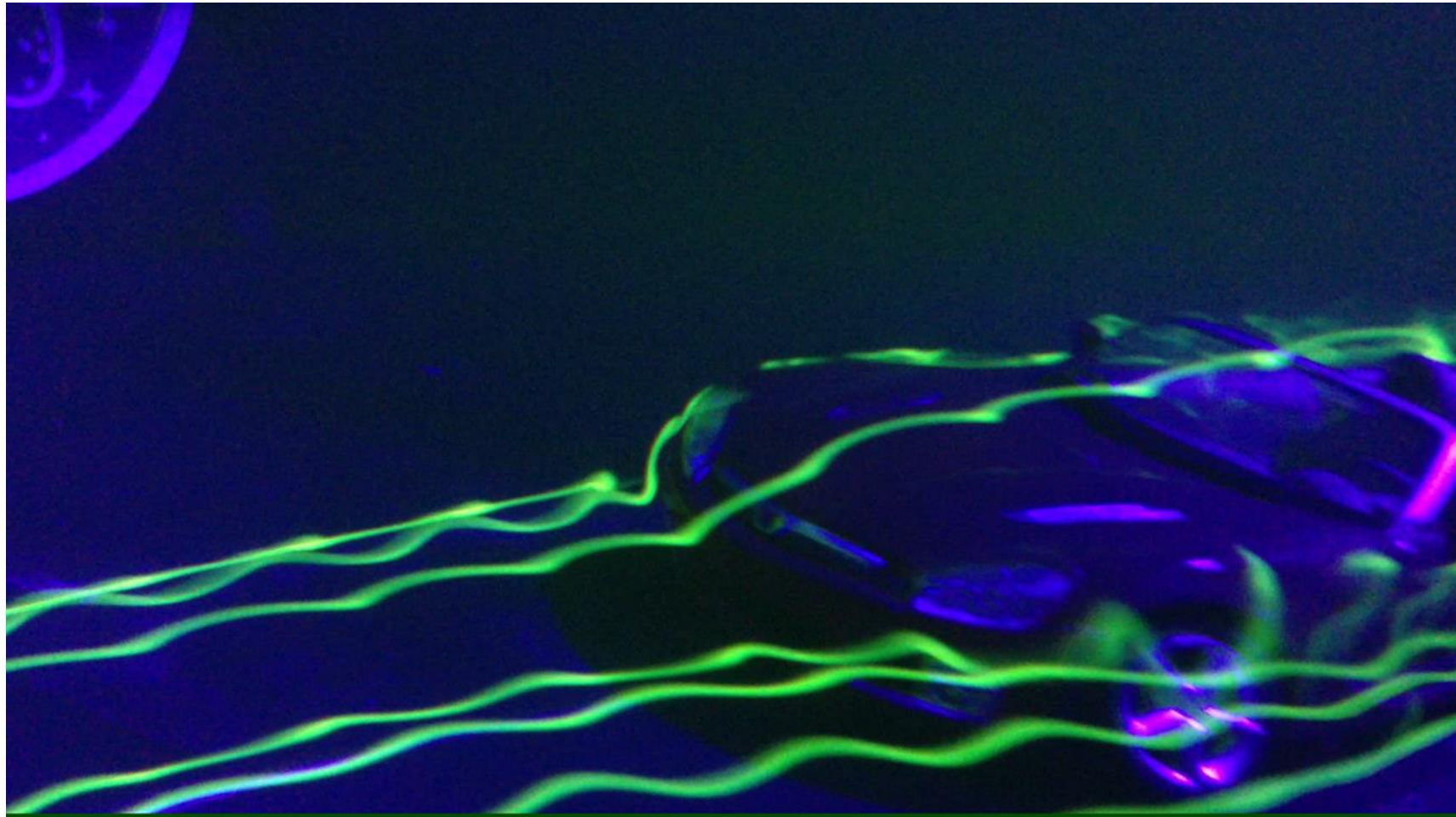
# COMPUTATIONAL FLUID DYNAMICS

- › 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

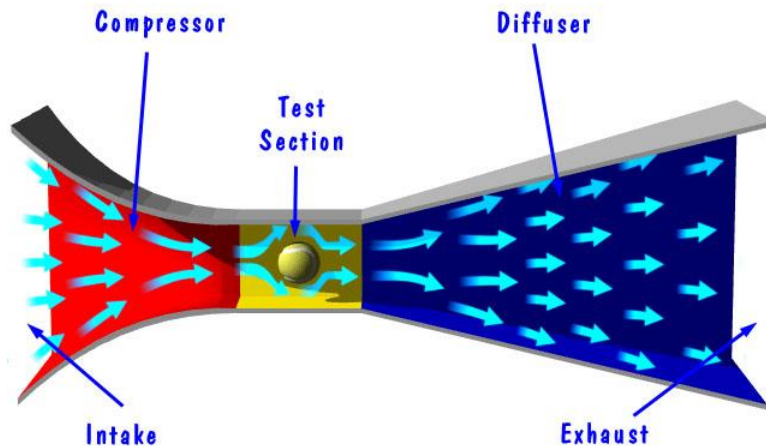




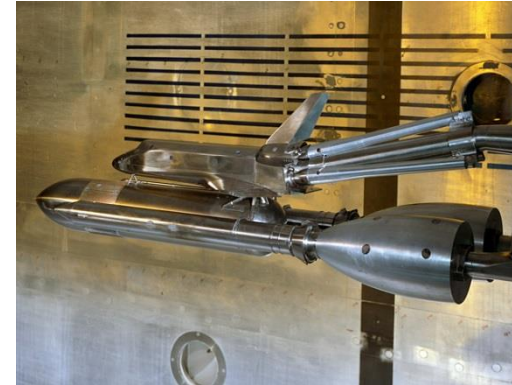
# SUMMER ASSIGNMENT: NATIONAL TRANSONIC FACILITY WIND TUNNEL

## WHAT IS A WIND TUNNEL?

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



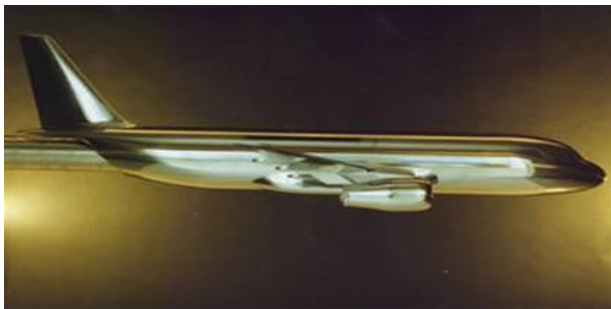
## NATIONAL TRANSONIC FACILITY



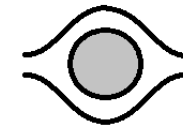
# NATIONAL TRANSONIC FACILITY WIND TUNNEL: WHY IS IT IMPORTANT?

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



$Re \ll 1$



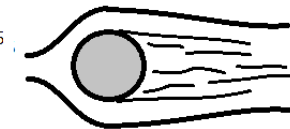
$Re \sim 10$



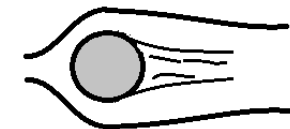
$Re > \sim 90$



$Re \sim 10^4 - \sim 10^5$



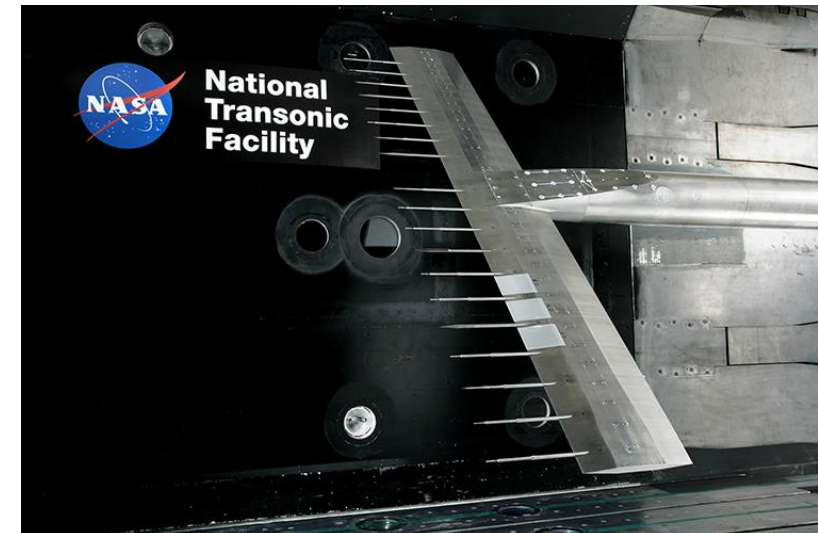
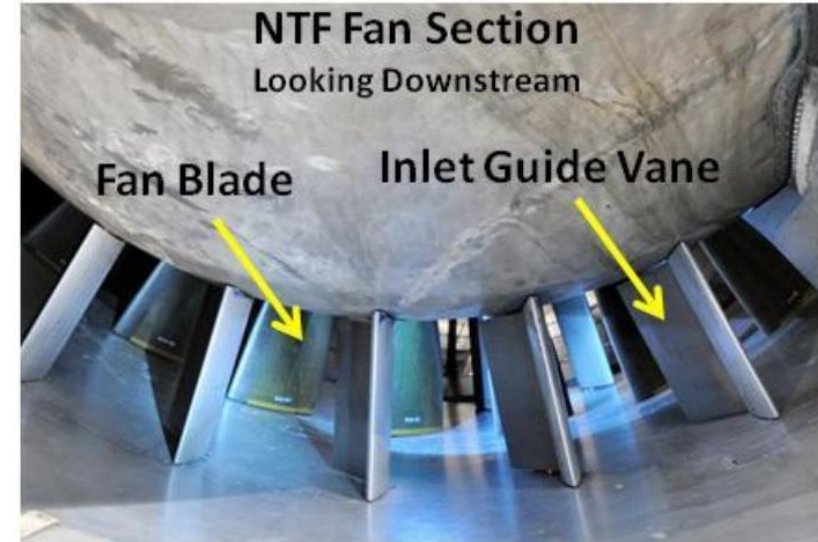
$Re > \sim 10^5$



# 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°F (colder than the surface of Jupiter!)
- › Sensor rake is used to measure temperature, pressure, velocity (crucial to understand turbulence in the test section)





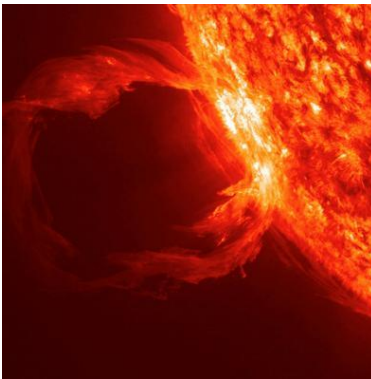
# NEXT SUMMER: NASA GODDARD

- › 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





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# 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

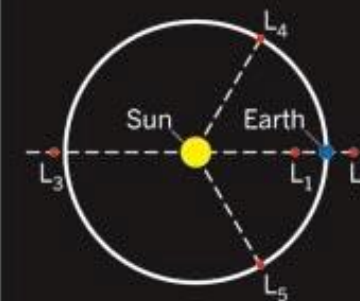
Once the mirror has unfolded, the JWST's 'spine' will hold it still and support the telescope's cameras and spectrographs.

## Secondary mirror

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

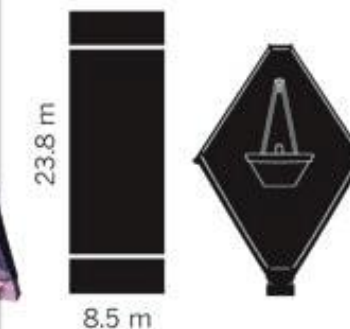
## LAGRANGIAN POINTS

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  $L_2$ .



## 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.



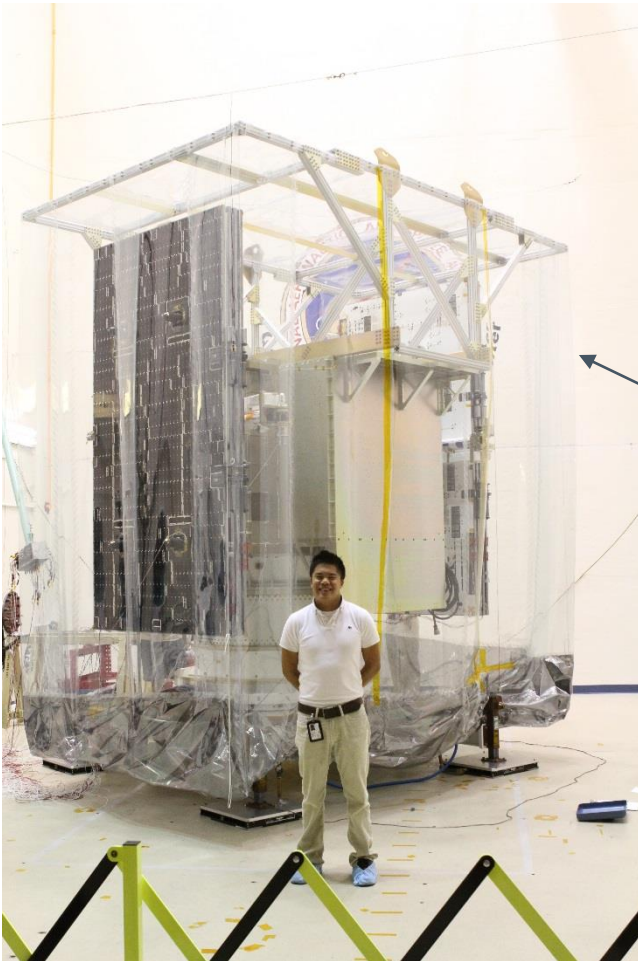


# VIBRO-ACOUSTIC ANALYSIS ON JWST

- › 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.**



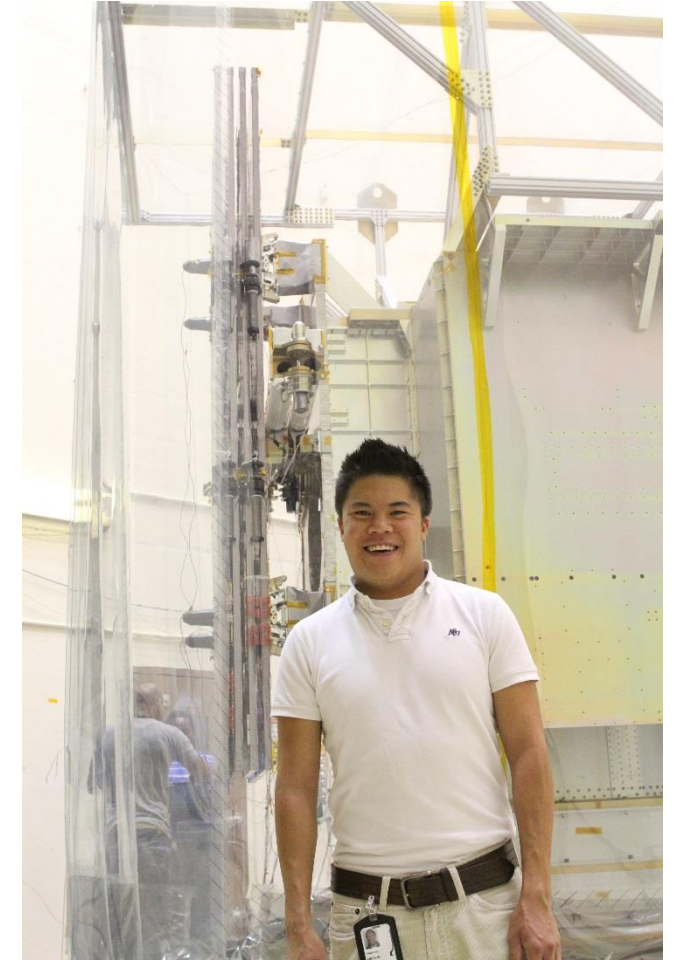
# ACOUSTIC TESTING (~170 dB!)



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 which, 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 plate rather than as true two-plate and honeycomb element. The simplification of multiple shell elements is done using the PSHELL card.

The MMS model also utilizes elements to represent joint features 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 (CEBUSH) and wider 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 PSHELL elements in NASTRAN to Salinas input. The PSHELL card defines the interlaminar, bending, transverse shear, and coupling properties of thin-shell elements. The PSHELL card also defines the structural properties of a honeycomb panel which are translated into Salinas and MMS input. For example, the cross-sectional moment of inertia (I) can be translated into the appropriate MMS input.

**NASTRAN Input**

Creating the PSHELL card for Honeycomb Panels

Outer Layer (Facesheets)

Material - references MAT ID  
Thickness - total thickness  
Fiber orientation - degrees  
Inner Layer (Honeycomb Core)

Material - references MAT ID  
Thickness - total thickness  
Fiber orientation - degrees  
Etc.

MID1, T - in plane load (facesheet) and total thickness  
MID2, 1/1211 - bending load (honeycomb) and inertia  
MID3, T<sub>1</sub>T<sub>2</sub> - shear load (honeycomb) and shear thickness

**MMS Modal Analysis**

Post-Column

Natural Frequency (Hz)	Percent Difference	
NASTRAN	Salinas	
141.1571	141.1571	0.000
244.1684	244.1684	0.000
344.1684	344.1684	0.000
444.1684	444.1684	0.000
544.1684	544.1684	0.000
644.1684	644.1684	0.000
744.1684	744.1684	0.000
844.1684	844.1684	0.000
944.1684	944.1684	0.000
1044.1684	1044.1684	0.000

Computes mode shapes and natural frequencies



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# LAST SUMMER: NASA AMES



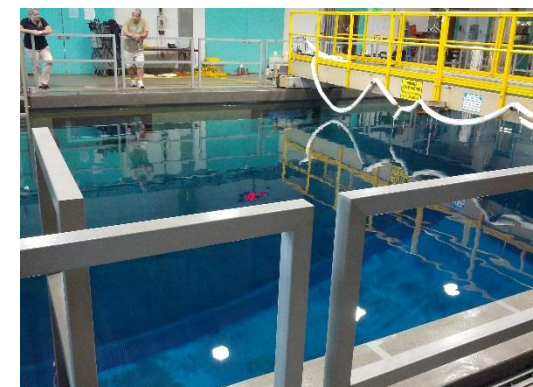
# NASA ACADEMY

- › 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

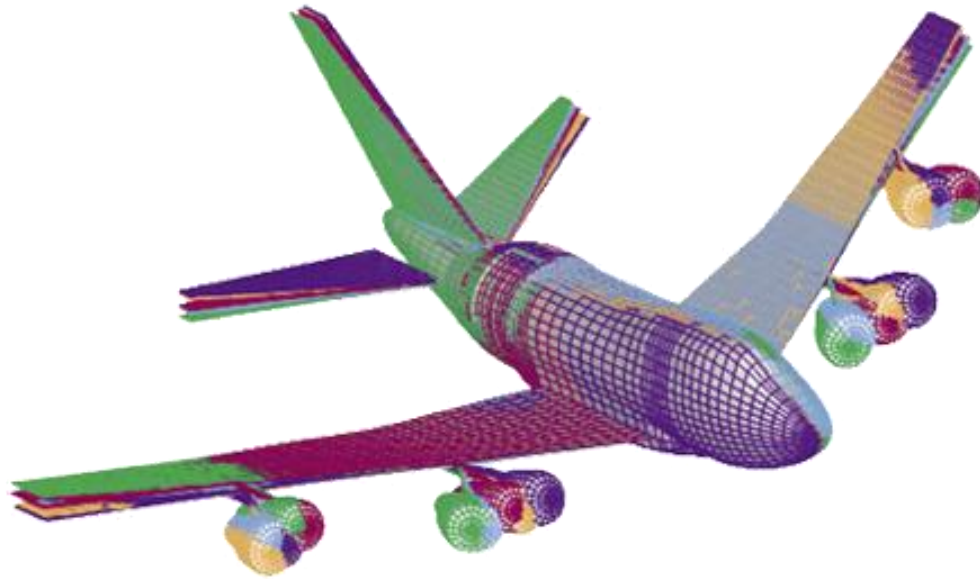




# NASA AMES RESPONSIBILITIES

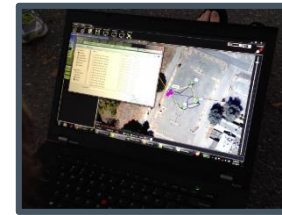
## INDIVIDUAL RESEARCH: AEROELASTIC MODELING

- › 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

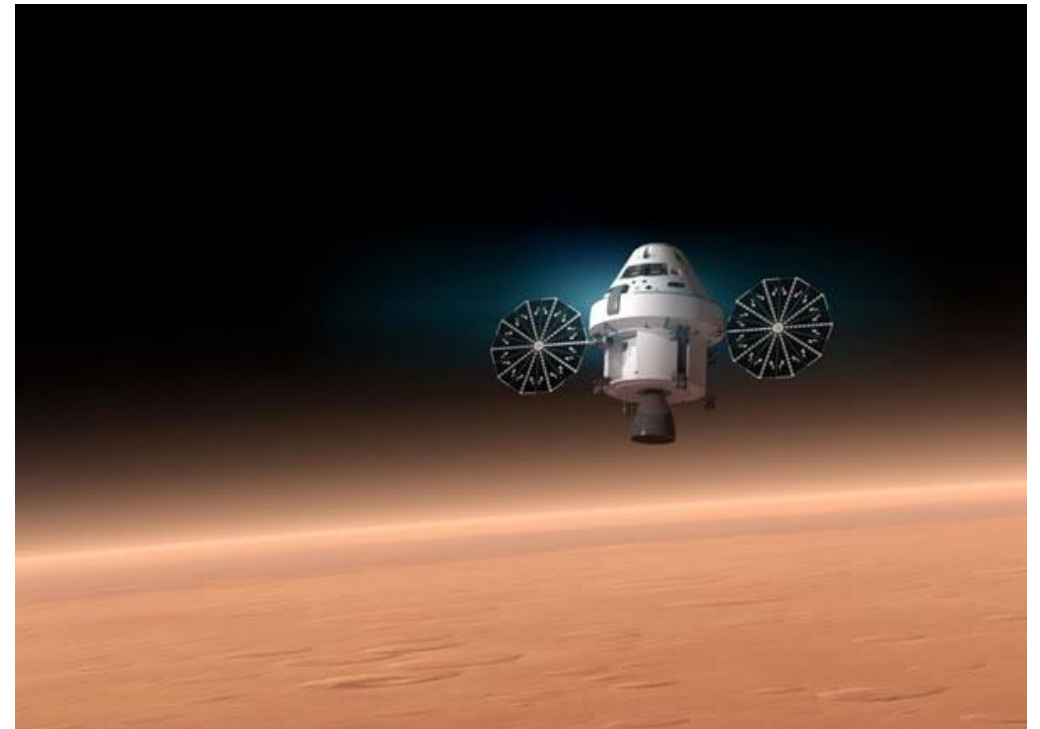
It extremely nerve-racking. Among the audience, included the center director, code-A chief engineer, and more (big named guys).

It was different being the expert in the room.



# NOW: LOCKHEED MARTIN - ORION

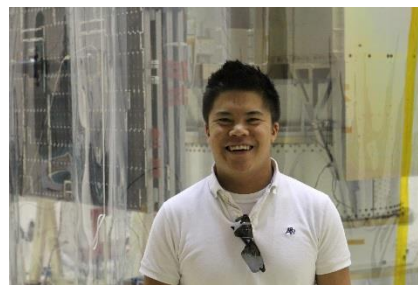
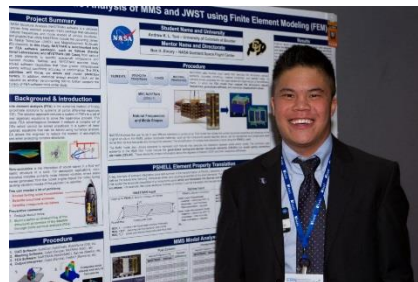
- › Flight Software Engineering
- › Fault Management: deals with detection, isolation, and recovery (FDIR) of malfunctions onboard the vehicle
- › Systems Engineering: requires broad understand of various subsystems of the spacecraft (propulsion, power, communication, etc.)





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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>