AC 2007-2619: INTRODUCING SIXTH THROUGH TWELFTH GRADE TEACHERS TO POWER AND PERFORMANCE EXPERIMENTS AS PART OF NATIONAL INSTITUTE OF AEROSPACE WORKSHOPS

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Introducing Sixth through Twelfth Grade Teachers to Power and Performance Experiments as part of National Institute of Aerospace Workshops

Abstract

The National Institute of Aerospace, NIA, was created near NASA's Langley Research Center in Hampton, VA on September 26, 2002, as a result of a winning proposal submitted by the AIAA and a 6-university team in response to a broad agency announcement. The four imperatives that framed center activities were to:

1. Conduct leading edge aerospace & atmospheric science research and develop revolutionary new technologies by creating innovative, collaborative, synergistic partnerships among NASA's Langley Research Center, academia, and industry,

2. Provide comprehensive graduate and continuing education in science and engineering by using both a local campus and exploiting innovative distance-learning concepts,

3. Incubate and stimulate the commercialization of new intellectual property developed through the Institute's activities, including radical ideas and disruptive technologies, and

4. Promote aerospace science and engineering and provide outreach to the region and nation.

In support of the fourth imperative, our workshops are to provide a brief yet thoughtful introduction to some of the important scientific and engineering challenges involved in NASA's complex missions and to relate this to grades 6-12 science and mathematics education. This paper describes our workshop components relating to power and performance and the experiences of teachers in learning more about propulsion and flight. Care was taken to provide teachers with basic materials so that they could stimulate young minds. Building on this, students should learn the basics early, build on the experience, and consider pursuing careers in science and engineering. Building on this, we want students to learn the basics early, to build on these basics, and to prepare for an education that will lead to careers in science and engineering.

Participation in the workshops has always been limited by space, schedule, and cost considerations, as well as by NASA Langley Research Center's other competing summer programs. Thus, in order to make a large impact, admission to the workshop is made through an application process which attempts to identify teachers who are most likely to benefit and to apply what they learn to their classes. Enrollments since inception in July, 2003 have been from 18 to 32 teachers. The 2006 summer workshop included 6-12 grade teachers for the first time from all states with NIA University participation including: Georgia, Maryland, North Carolina, and Virginia.

In all four workshop years, our NC participants were able to operate a turbojet engine and were provided instruction in the theory of the jet-propulsion cycle. The

turbojet engine used in the workshop is a single-stage radial-flow compressor, a single-stage axial-flow turbine, and a reverse-flow annular combustion chamber. The turbojet engine is equipped with a data acquisition system to monitor engine speed, exhaust gas temperature, fuel flow, and thrust. There has been a great deal of assessment and some follow-up from the teachers on how the sessions have helped them in the classroom. Safety is a high priority with us, as is hands-on operation. Teachers are instructed in both. There is also a great deal of assessment at the workshop as well as follow-up assessment from the teachers on how the sessions have helped them in the classroom.

Introduction

This paper describes the experiences the teachers gained in the areas of propulsion, gas turbine engines, and flight. This session of the workshop introduces the teachers to the basic principles of the gas turbine engine. During this workshop session the teachers actually learn how to operate a gas turbine engine, collect and analyze the output data including thrust and efficiency, Figures 1-3. Care was taken to provide teachers with basic materials so that they could stimulate young minds. Building on this, students should learn the basics early, build on the experience, and consider pursuing careers in science and engineering.

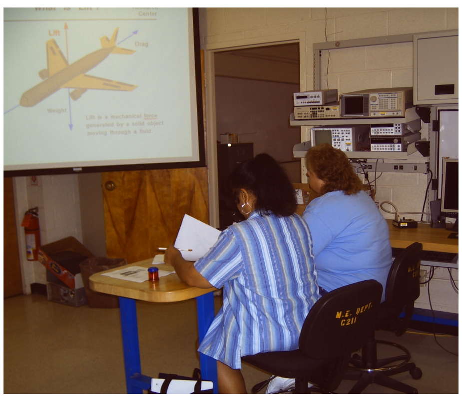


Figure 1. The Basics of Lift, Gravity, Thrust, and Drag

Figure 2. Waiting for a Chance at the Throttle

Figures 3. First Time on the Throttle (2005 and 2006 Workshops)

Background

The first successful development of gas turbines was in 1930s. The early gas turbines built in 1940s and 1950s has cycle efficiencies of about 17% mainly due to the following:

1. Low compressor and turbine efficiencies
2. Low turbine inlet temperatures due to metallurgical limitations of those times.

Gas turbines are very versatile and have the ability to burn a variety of fuels. The two major application areas of gas turbine are aircraft propulsion and electric power generation. Gas turbine are widely used to power aircraft because they are light and compact and have a high power to weight ratio. When it is used for aircraft propulsion, the gas turbine produces just enough power to drive the compressor and auxiliary equipment, such as a small generator and hydraulic pumps. The high velocity exhaust gases are responsible for producing the necessary thrust to propel the aircraft[4].

Gas Turbine Experiment

Gas turbine engine (common name jet engine) operates on the application of Sir Isaac Newton's third law of physics: *for every action there is an equal and opposite reaction.* This law is demonstrated in simple terms by releasing an inflated balloon and watching the escaping air propel the balloon in the opposite direction.

The gas turbine has three main sections the compressors, the combustion system, and the turbines.

1. The compressor draws air into the engine, pressurizes it, and delivers it to the combustion chamber. It is driven from the turbine by a shaft. There are two types of compressor: the centrifugal flow impeller type, and the axial flow type. Axial compressors can achieve compression ratios in excess of 40:1.

2. The combustion chamber receives air from the compressor which mixes with fuel sprayed from nozzles in the front of the chamber. The burning process is initiated by igniter plugs, isolated after start-up, and remains continuous until the fuel supply is shut off.

3. The turbine consists of one or more stages of alternate stationary and rotating aerofoil-section blades. The rotating turbine blades are carried on discs, which are connected by a shaft to the compressor. The stationary blades - nozzle guide vanes - are housed in the turbine casing. The turbine extracts energy from the hot exhaust gases to drive the compressor.

There are four main types of gas turbine: turbojet, turbofan, turboprop, and turboshaft. The turbojet and turbofan are both reaction engines which derive power from the reaction to the exhaust stream. The turboprop and turboshaft operate differently by using the exhaust stream to power an additional turbine which drives a propeller or output shaft.

1. **The Turbojet** is the simplest form of gas turbine and relies on the high velocity hot gas exhaust to provide the thrust. Its disadvantages today are its relatively high noise levels and fuel consumption.

2. **The Turbofan** or 'bypass' engine the partly compressed airflow is divided, some into a central part - the gas generator or core - and some into a surrounding casing - the bypass duct. The gas generator acts like a turbojet while the larger mass of bypass air is accelerated relatively slowly down the duct to provide 'cold stream' thrust. The cold and hot streams mix to give better propulsive efficiency, lower noise levels, and improved fuel consumption.

3. **A Turboprop** uses a propeller to transmit the power it produces. The propeller is driven through a reduction gear by a shaft from a power turbine, using the gas energy which would provide the thrust in a turbojet.

4. **A Turboshaft** is a power plant for helicopters. Like the turboprop, it also uses a power turbine and gearbox, though in this case the power is transmitted to the helicopter's rotor system. This type of engine is also used in industrial and marine applications.

There are two additional variations to the gas turbine engine the afterburning and the vectored thrust.

Afterburning, or reheat, increases engine thrust for short periods to improve aircraft take-off, climb and combat performance. Because the fuel in a gas turbine burns in an excess of air, sufficient oxygen remains in the exhaust to support further combustion, particularly in a turbofan. By injecting and burning additional fuel in the jet pipe, the exhaust velocity and consequently the engine thrust is increased.

Thrust vectoring was developed for short take-off and vertical landing (STOVL) aircraft. The unique example of this concept is the Harrier 'jump-jet'. The engine has four linked, swiveling nozzles to direct the gas stream from vertically downward for upward lift, through an arc to horizontally rearward for conventional forward flight. The bypass air is discharged through the two front nozzles and the hot gas exhaust through the two rear nozzles.

The gas turbine experiment will be conducted using the SR-30 turbojet engine manufactured by "The Turbine Technologies, LTD", Figure 4. is a cut-away view of the SR-30 model gas turbine engine and Figure 5. shows its major engine components.

The SR-30 turbo jet engine is comprised of:

1. A single stage axial flow turbine,
2. Radial flow compressor and
3. Reverse flow annular combustion chamber.
4. The engine is of single shaft design.

5. Both the compressor and turbine rotate on the shaft at the same speed.
6. The engine is fully throttleable from an idle speed of 45,000 rpm to a maximum speed of up to 90,000 rpm.

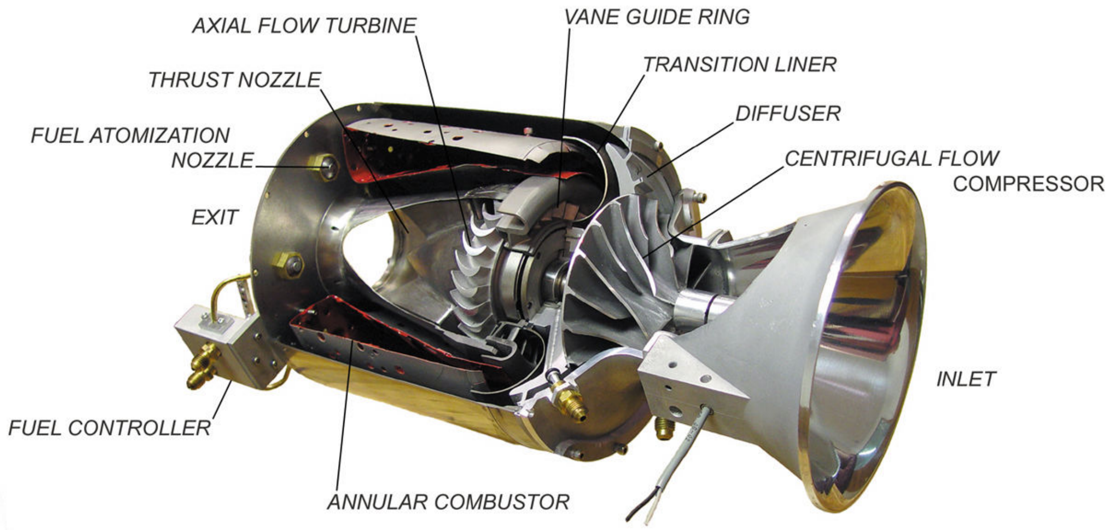


Figure 4. Cut-Away View of Turbine Technologies SR-30 Gas Turbine Engine[1]

Figure 5. Turbine Technologies SR-30 Major Engine Components[1]

Jet-Propulsion Cycle

Aircraft gas turbines operate on an open cycle Figure 6 called jet-propulsion cycle. The ideal jet-propulsion cycle differs from the simple ideal Brayton cycle in that the gases are not expanded to the ambient pressure in the turbine. Instead, they are expanded to a pressure such that the power produced by the turbine is just sufficient to drive the compressor and the auxiliary equipments. That is, the net work output of the jet propulsion is zero (in the ideal case, the turbine work is assumed to equal the compressor work). The gases that exit the turbine at relatively high temperature and pressure are accelerated in a nozzle to provide the thrust to propel the aircraft. The process can be simplified as follows:

- Fresh air at ambient conditions is drawn into the compressor, where its temperature and pressure are raised.
- The high pressure air proceeds into the combustion chamber, where the fuel is burned at constant pressure.
- The resulting high temperature and pressure gases then enter the turbine while producing power. The power produced by the turbine drives the compressor.
- The high-temperature and high-pressure gases leaving the turbine are accelerated in a nozzle to provide thrust.

Specifications of the Turbine Technologies SR-30 Turbojet Engine

Diameter:	6.75 inches
Length:	10.75
Max. RPM:	90,000
Max. Exhaust Gas Temperature EGT:	720º C
Pressure Ratio:	3.4
Specific Fuel Consumption:	1.18
Engine Oil:	Turbine Oils meeting military specification Mil-L-236993C (Exxon 2380 Turbo oil and Aeroshell 500)
Approved Fuels:	
Commercial Grades:	Jet A, Jet A-1, Jet B, Kerosene, Diesel, Heating fuel oil #1 or #2
Military Grades:	JP-4, JP-5, JP-8

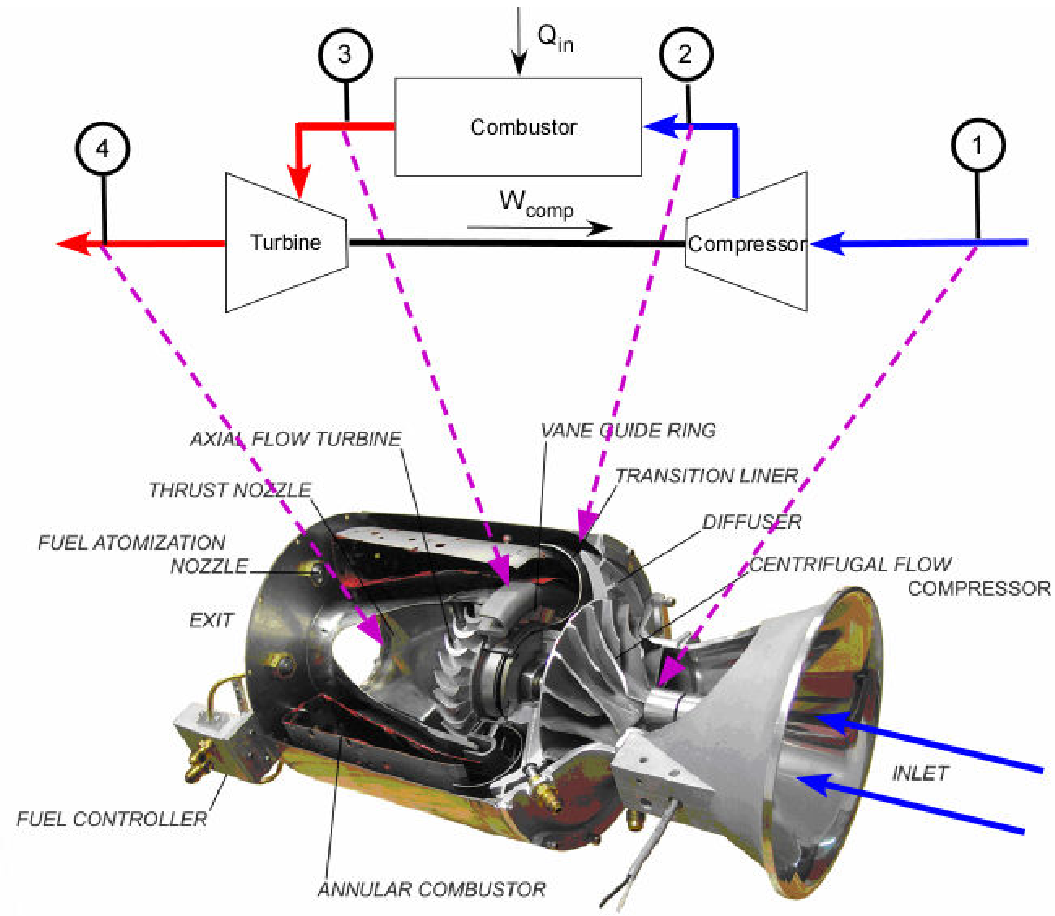


Figure 6. Schematic of Jet-Propulsion Cycle and Cut Away of SR-30 Engine

Experimental Procedures

<u>Before Engine Start</u>

1.	Compressor Rotor:	Rotate by hand. Check for smooth rotation.
2.	Fuel Quantity:	Check
3.	Oil Quantity:	Check
4.	Ventilation:	Ensure adequate room ventilation
5.	Hearing Protection:	In Place
6.	Eye Protection:	In Place
7.	Fire Extinguisher:	Accessible
8.	Starting Air:	Connected (100 psi minimum) a compressed air source is required for engine starting (engine starting is accomplished via compressed air impingement)

<u>Engine Starting</u>

1.	Air Pressure:	100-120 psig
2.	Master Switch Key:	ON
3.	Red Low Oil Pressure Light:	ON
4.	Electronics Master Switch	ON
5.	All LED Instruments	ON

6. Throttle — Engine Start Position
7. Ignitor Switch — ON
8. Digital EGT Readout — Green Digits (Below 100º C)
9. Air Starter Switch — ON
10. Fuel Switch — ON at 7,000 RPM

After Start

1. Ignition Switch — OFF
2. Air Start Switch — OFF
3. Throttle — Idle (check for normal engine instrument indications)
4. Engine Instrumentation — Monitor Throughout Run

Normal Shutdown

1. Idle Engine — at 10 psig (combustion chamber pressure) for one minute
2. Fuel Switch — OFF

Emergency Shutdown

1. Fuel Switch — OFF
2. Ignition Switch — OFF
3. Air Start Switch — ON for Cooling
4. All Switches — OFF Below 85º C EGT

Engine Sensor Location and Data Acquisition System

The Turbine Technologies, LTD Gas Turbine engine [1] comes equipped with a turnkey data acquisition system Figure 7. Thirteen data points (pressures, temperatures, thrust, rpm, and fuel flow) are collected via sensors located at each key engine station. Engine sensor locations are shown in Figure 8.

- Compressor Inlet Pressure, **P1** (Displayed on Data Acquisition Screen)
- Compressor Inlet Temperature, **T1** (Displayed on Data Acquisition Screen)
- Compressor Exit Pressure, **P2** (Displayed on Data Acquisition Screen)
- Compressor Exit Temperature, **T2** (Displayed on Data Acquisition Screen)
- Turbine Inlet Pressure, **P3** (Displayed on Panel and Data Acquisition Screen)
- Turbine Inlet Temperature, **T3** (Displayed on Panel as TIT and Data Acquisition Screen)
- Turbine Exit Pressure, **P4** (Displayed on Data Acquisition Screen)
- Turbine Exit Temperature, **T4** (Displayed on Data Acquisition Screen)
- Exhaust Gas Pressure, **P5** (Displayed on Data Acquisition Screen)
- Exhaust Gas Temperature, **T5** (Displayed on Panel as EGT and Data Acquisition Screen)
- Fuel Pressure (Displayed on Panel)
- Engine shaft speed, **RPM**, Tachometer Generator (Displayed on Panel and Data Acquisition Screen)

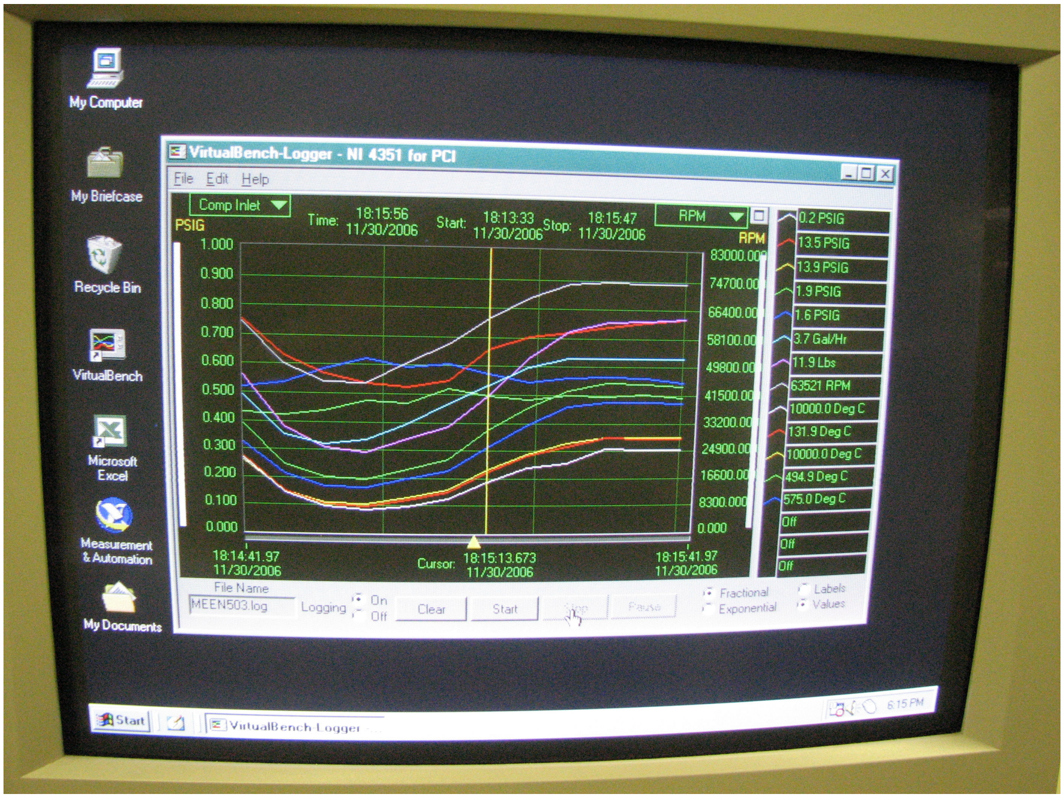


Figure 7. Data Acquisition Screen of the Mini-Lab

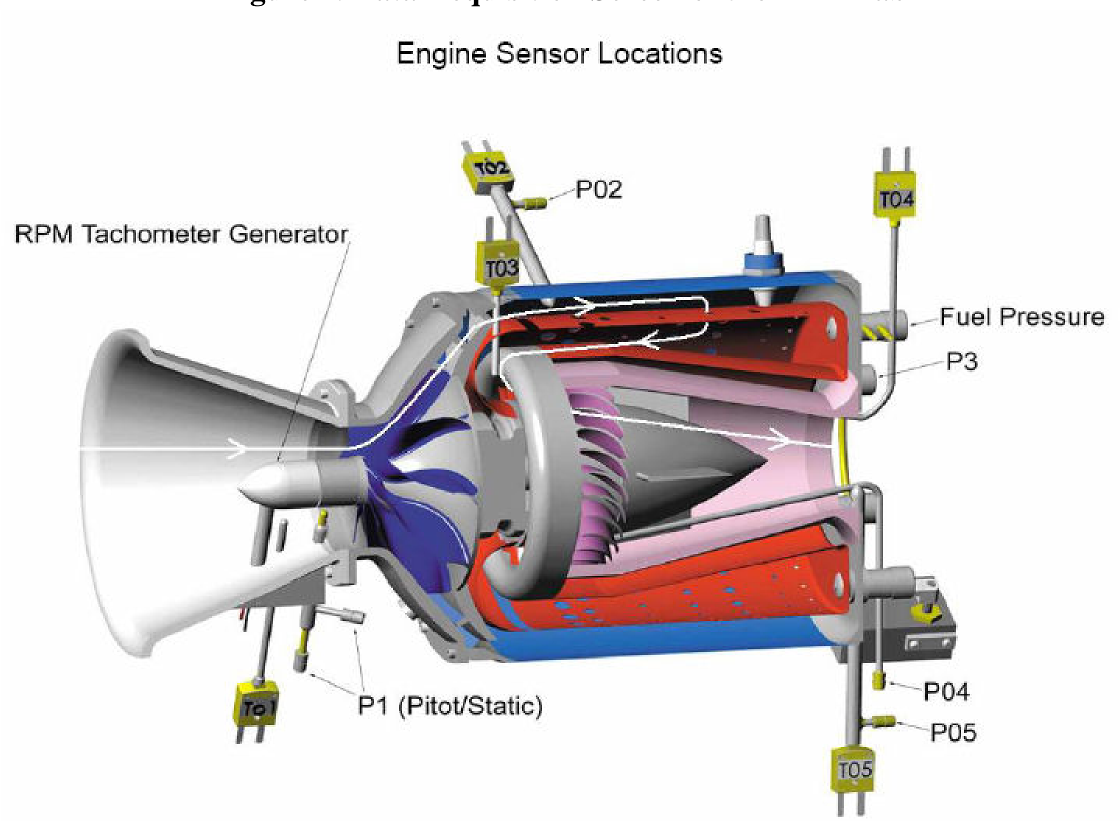


Figure 8. Engine Sensor Locations of SR-30[1]

Cycle Analysis and performance

Refer to the schematic diagram of the jet-propulsion cycle, which is made up of four irreversible processes:

1 – 2 Isentropic compression (in a compressor)
2 – 3 Constant-pressure heat addition
3 – 4 Isentropic expansion (in a turbine)
4 – 1 Constant-pressure heat rejection

Thrust

The thrust developed in a turbojet engine is the unbalanced force that is caused by the difference in the momentum of the low-velocity air entering the engine and the high-velocity exhaust gases leaving the engine, and it is determine from Newton's second law. The pressures at the inlet and exit of a turbojet engine are identical (ambient pressure).

Recall Newton's second law

$$F = ma$$

Where

$$a = \frac{dv}{dt}$$

Therefore,

$$F = \frac{d}{dt}(mv)$$

$$Fdt = d(mv)$$

Integrate

$$\int_{t_1}^{t_2} Fdt = \int_1^2 d(mv)$$

$$F(\Delta t) = (mv)_2 - (mv)_1$$

$$F = \frac{(mv)_2 - (mv)_1}{\Delta t}$$

$$F = (\dot{m}\,v)_{exit} - (\dot{m}\,v)_{inlet}$$

$$F = \dot{m}(v_{exit} - v_{inlet})$$

Where

$F \equiv$ Thrust Force

$\dot{m} \equiv$ Mass flow rate of air through the engine

$v_{exit} \equiv$ The exit velocity of the exhaust gases

$v_{inlet} \equiv$ The aircraft velocity, assume the aircraft cruising in still air

$(\dot{m}v)_{inlet1} \equiv$ Rate of linear momentum of the inlet flow

$(\dot{m}v)_{exit} \equiv$ Rate of linear momentum of the hot exhaust gases

Propulsive Power

The power developed from the thrust of the engine is called the propulsive power, which is the thrust times the aircraft velocity.

$$\dot{W}_P = FV_{aircraft}$$

Propulsive Efficiency

The propulsive efficiency is the ratio of the desired output to the required input. The desired output is the power produced to propel the aircraft and the required input is the heating value of the fuel

$$\eta_P = \frac{\dot{W}_P}{\dot{Q}_{in}}$$

$$\dot{Q}_{in} = \dot{m}HV_{fuel}$$

Where HV_{fuel} is the heating value of the fuel

Experimental Results

Figures 9-14 show the output results obtained from the data acquisition system.

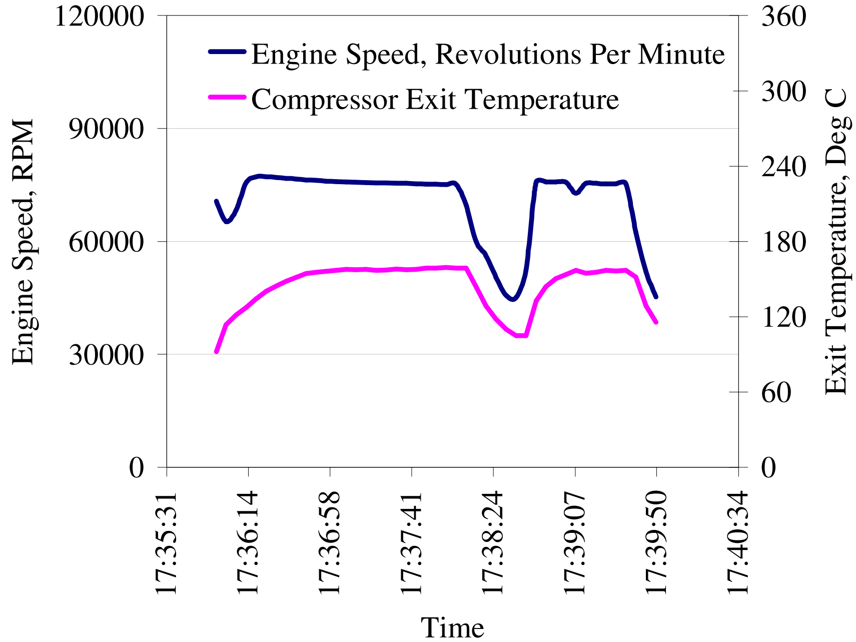


Figure 9. Compressor Exit Temperature and Engine Speed versus Time

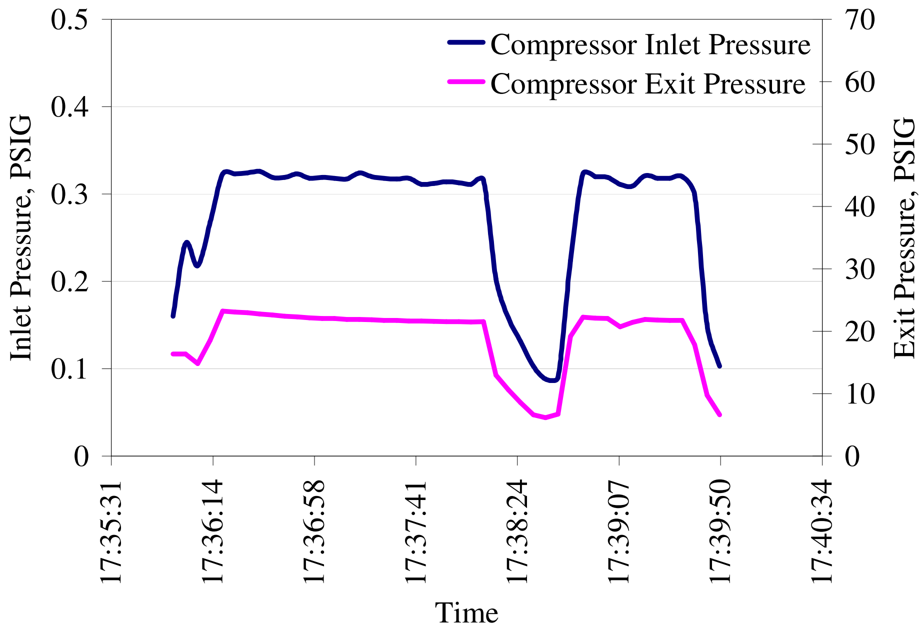


Figure 10. Compressor Inlet and Exit Pressure versus Time

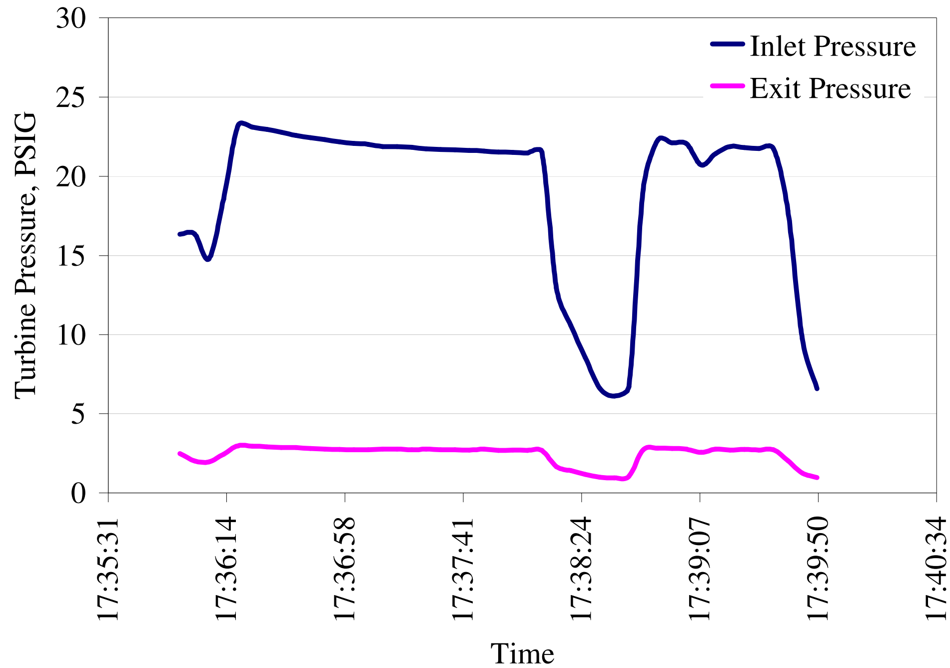


Figure 11. Turbine Inlet and Exit Pressure versus Time

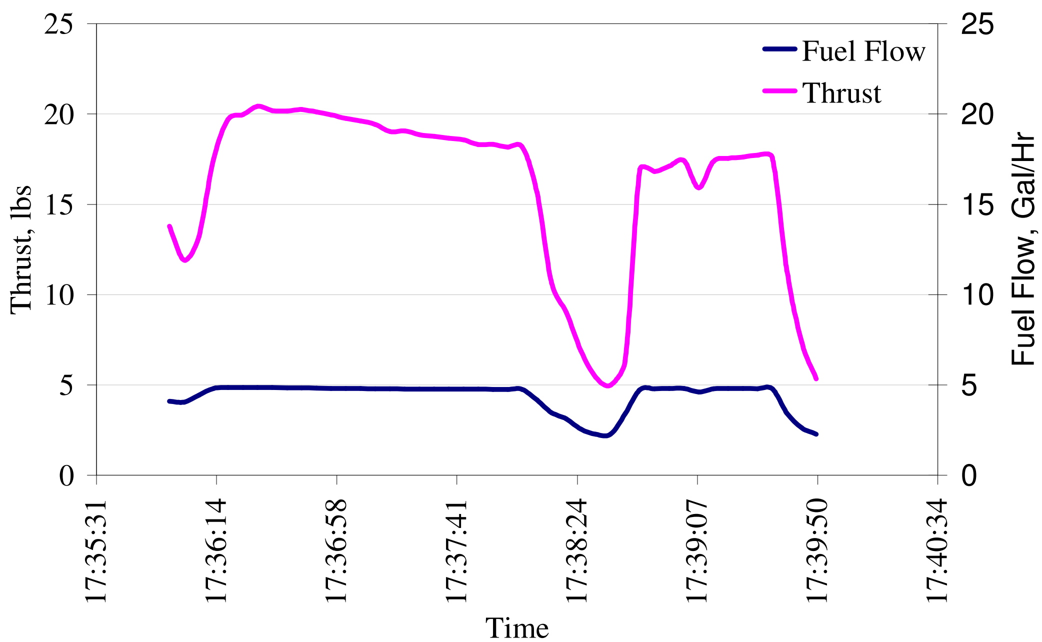


Figure 12. Fuel Flow and Thrust versus Time

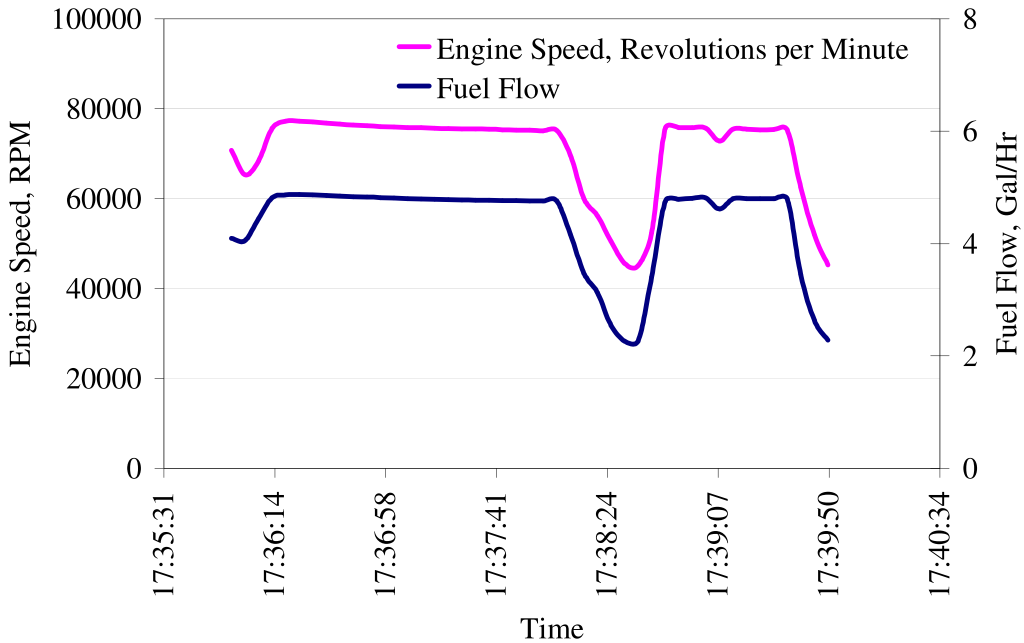


Figure 13. Engine Speed and Fuel flow versus Time

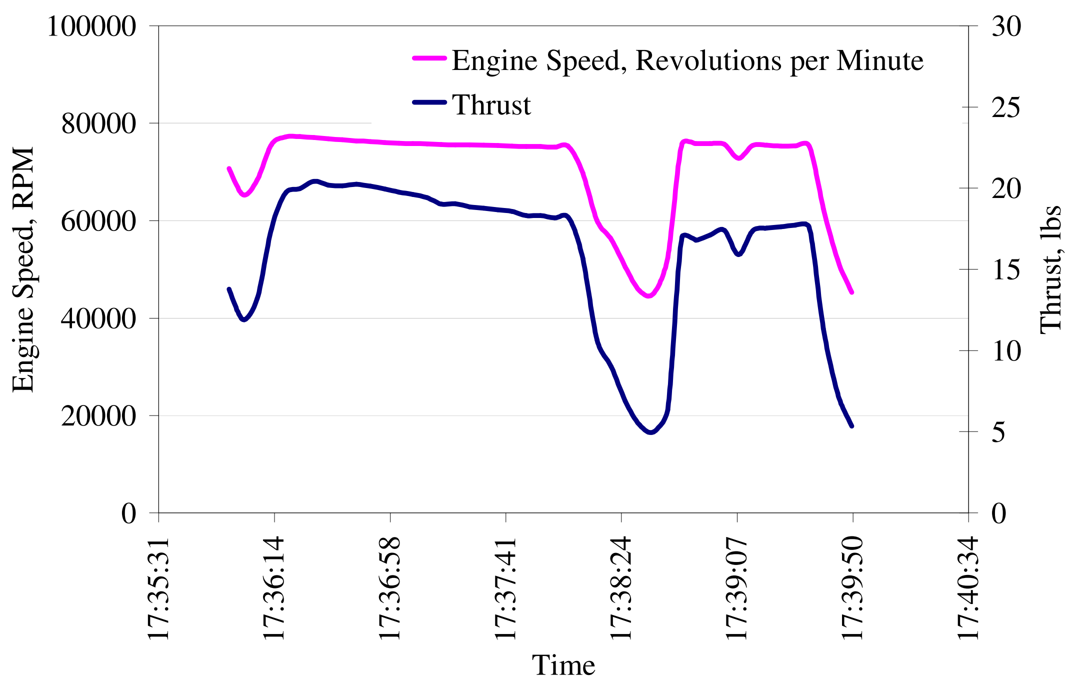


Figure 14. Engine Speed and Thrust versus Time

Participant Statistics

Tables 1-3 below provide aggregate demographic and classroom specialization data on our 2006 participants. There was diversity in gender and race, and the participant pool represented a variety of educational specializations and levels.

North Carolina and Georgia 2006 Workshop participants spent week 1 at NASA's Langley Research Center and week 2 in North Carolina for our University program. Other participants, with one exception, attended the Virginia second week Program. All participants attended the NASA LaRC on-site program during the first week. The table below indicates their subject area and some interesting background statistics. 9 members of this group were North Carolina residents, and 6 members were Georgia residents. For comparison, note the breakdown in the teaching

Teachers in the 2006 Summer Workshop. NC and Georgia Participants are included here. Other participants, with one exception, attended the Virginia second week Program. All participants attended the NASA LaRC on-site program during the first week.

Table 1. 2006 Participant by Grade Taught, State, and Major Awards

HS: Teaching Topics	**State**	**Selected Special Awards/Honors of this year's participants**
3 AP Physics/ Physics	9 – North Carolina	Past Finalist in NASA's Educator Astronaut Teacher Program
Marine Ecology	6 - Georgia	Governor's Award for Excellence in Educational Teaching
2 AP Biology and Biology		Peace Corp Participant
3 Chemistry , 2 Physical Science		Kenan Fellow
Zoology, Astronomy		She is a former US Navy Photographer
		He had 17 student experiments selected to fly in space by NASA
Pre-HS Topics		Armed Forces Expeditionary Medal
Middle School Math		Star Teacher in her School & County.
6th Grade Math and Science		

Past Assessment Activities

During years 2003-2005, we have statistics on the impact of the workshop and activities. These are listed briefly below from the original 2003 workshop.

The average score for NASA Langley workshops has always been in the upper level of a 5 point scale, ranging from 4.50 to 5.0. There evaluations by the teachers for this workshop are presented in aggregate below:

Table 2. PROGRAM CONTENT: Which of the following topic areas were addressed in your program?

Topic	Responses	Percentage*
Science	25	96.2
Mathematics	26	100.0
Engineering	19	73.1
Technology	23	88.5
Other	6	23.1

*Percents are calculated based on the number of participants responding to this question. The percent for "Nothing Selected" is based on the total number of participant reports. Please note that percentages can add up to more than 100% as participants can select multiple options.

Table 3. PROGRAM VALUE

Statement	Responses*
This program was a valuable experience	4.9
The content of this program matched your school's or school system's educational objectives	4.8
This program helped you better understand careers in science, mathematics and technology:	4.8

* 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree 1=Strongly Disagree, 0=No Rating Checked.

The University Program (week 2) for 2006

The workshop program conducted at A&T during July, 2006 was conducted over 2.5 days. While the focus of this report is on an introduction to aviation propulsion, we list it in its entirety in Excel format.

The 2006 workshop participants have been recently sent a set of electronic instructional materials and videos of presentations. This is a four DVD set that has been complied of highlights. The avi files are short segments of the presentations; there are instructor handouts and PowerPoint files, and lots of photos of specific events that should be helpful to the participants.

Table 4. Week 2 portion of the 2006 Teacher workshop Sessions at North Carolina A&T State University

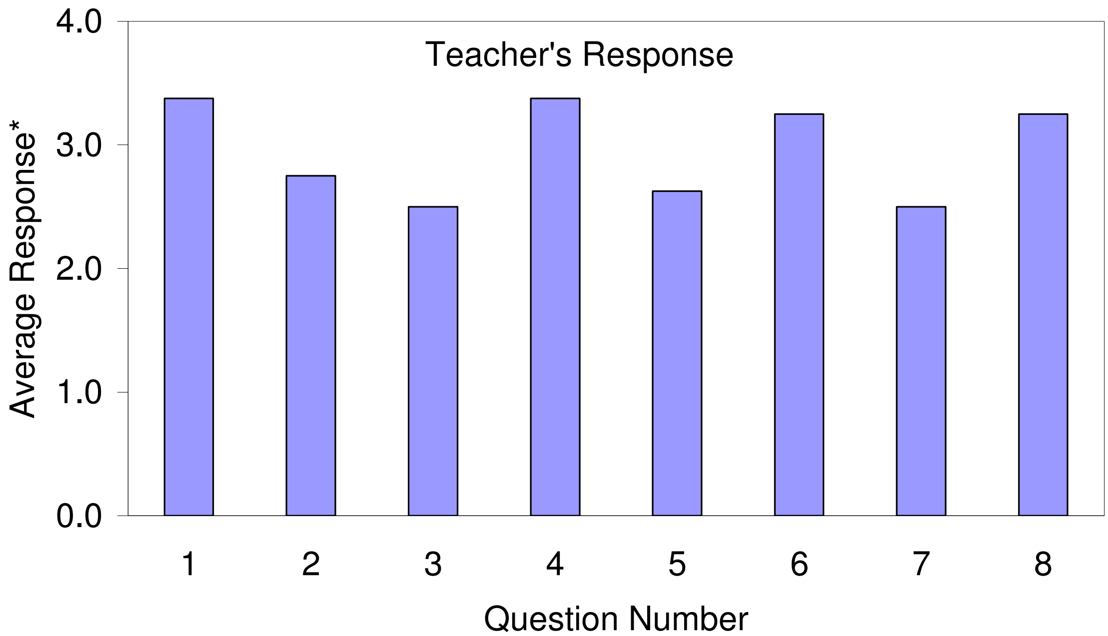
Wednesday, July 19, 2006 (NC A&T)	Thursday, July 20, 2006 (NC A&T)	Friday, July 21, 2006 (NC A&T)
Coffee and Bagels (8:00-8:30) IRC 410	Coffee and Bagels (8:00-8:30) IRC 410	Coffee and Bagels (8:00-8:30) IRC 410
Cosmology (8:30-9:30) *Dr. Stephen Danford* IRC 410	Demonstration and Lecture on the types and properties of composite materials *Prof. Robert Sadler* IRC Lobby	Mechanical Testing of Samples Statistical Analysis of Strength Material Properties* (8:30- Dr. Ajit D. Kelkar IRC Lobby
Gas Turbine Experiment* (9:30-10:30) *Dr. Messiha Saad* IRC Lobby	Microscopy a modern tool for (How and Why do materials fail) (9:30-10:30) *Dr. Zhigan Xu and Dr. Cindy Waters* IRC Lobby	Smart Materials for Space Travel Discussion and Demonstration* (9:30-10:30) *Dr. Mannur Sundaresan* IRC Lobby
Aggie One-Card 215 memorial Union ID's will be made	Teacher Share Time (10:30-11:30) IRC 410	Check out of Aggie Suites Workshop assessment (some) Teacher share time (10:30-11:30) Mc Nair 410
Lunch (11:30-12:30) IRC 410	Lunch (11:30-12:30) IRC 410	Video-Conferenced Teacher Presentations (12:15-1:30) McNair Lecture Room IV (second (Food/Drinks Not Allowed in the
(Pisgah Astronomical Research Institute) PARI - a Laboratory to Study Science (12:30-2:15) *Mr. Don Cline, President of PARI* IRC 410	Prepare Samples of Composites for Mechanical Testing* (12:30-2:15) *Dr. Ajit D. Kelkar* IRC Lobby	
Basic Astronomy - How to include Space Science Content into your classroom unit plans (2:15-3:15) *Dr. Abebe Kebede* IRC 410	Break (2:15-2:30)	
Break & Travel to Winston Salem (3:15-4:00)	Translating Space Exploration Research into Meaningful Experieces for Students (2:30-4:00) *Dr. Gregory Goins* IRC 410	
Teaching Through Robotics (3:30 - 4:30) Presenter: Jim Bott & Kevin Barnard		

Teacher Post-Workshop Assessment Activities for 2006

The following questions were included in the assessment form, and the results are shown in Figure 15:

1. I had an interesting and positive experience at A&T.
2. The information provided was useful in my lesson planning.
3. I incorporated information from the workshop into the classroom curriculum.
4. I would recommend the workshop to teachers whom I know.
5. I was able to apply my workshop experience to improve my teaching.

6. The technical information in the workshop enhanced my understanding of important science topics.
7. I was able to apply what I learned to enhance the education of my students.
8. As a result of the workshop, I better understand how engineers and scientists contribute to enhancing human knowledge of the universe.



* 4 = Strongly Agree, 3 = Agree, 2 = No opinion/neutral, 1 = Disagree, 0 = strongly disagree.

Figure 15. Result of the Teacher workshop Assessment of 2006.

Additional survey Questions:

Question #1

We asked the workshop participants to indicate how they used the information provided in the workshop to improve their teaching and to add innovation to their student learning and to curriculum. These are some of the comments we received:

> "As a former engineer and now physics teacher, I was already aware of the many ways engineering can be related to teaching and learning. One thing that I use from the workshop is the concept of the work breakdown structure to organize curriculum. I also like visiting the labs and seeing how data is collected for research. Although it is a challenge to adapt some of the sophistication of an engineering college curriculum to the high school level, attending the workshop at A&T helps me enrich and enhance learning for my higher level physics students".

> "The information at A&T was very technical, and much of the time was focused on lectures which were not very applicable to my 9th grade students. There were

a couple of presentations that I thought were valuable, they just were not applicable to me personally".

"Have worked with PARI (Pisgah Astronomical Research Institute) to try and obtain grants. Also use PARI and other remote site radio/optical telescopes to enhance learning with "Hands on" Learning".

"Have discussed concept of composites in Physical Science, but still have not developed effective lesson plans. Robotics is now a thought, but need more information".

"As I have just started the chemistry goal I am finding some of the polymers and strength testing aspects to be useful".

"I have only used a small percentage because it takes time given how much we experienced. Over time, the incorporated content from the workshop will increase".

"The majority of the information I use is about the seriousness of our lack of engineers in our school systems. I relate the testing and research we saw to the students in hopes of encouraging a few future engineers".

"As a result of coming to A&T, it sparked many ideas of lessons that I could create for my students as well as grants that I wanted to write to incorporate math, science and technology as well as literature together. I really enjoyed the woman from the after school program. She created the kit and gave us each one. That is something that I have strived to do within my classes for units as well as when writing grants. To have something to give to participants is a HUGE plus!! I loved the idea of seeds with gravity and without".

"The information gave me a context to teach important concepts".

Question #2

We asked the workshop participants to provide any additional information that is relevant to their workshop experience at A&T. These are some of the comments we received:

"It's always good to foster relationships between all levels of schooling. I am also the Chair of the AAPT Committee on High Schools and by networking through the A&T (and in general the NIA experience) I have nurtured ideas and perhaps additional workshops to pursue as part of the AAPT National Meetings. Our meeting this year is in Greensboro and I believe our AAPT Committee on Minorities is planning something special to highlight the role of physics at HBC".

"The Langley and NC State portions of the workshop were much more practical. I was a little disappointed that I could not take more away from the A&T portion".

"Overall great experience. Think some topics were a little drawn out and configured in a confusing "take and use" format. Would really like to see lessons and activities that are organized to support the NCSCS that could be demonstrated and then used right out of the box. This would be similar to how the military has developed its teaching philosophy. An example would be composites. Give application, show integration with K-12 learning SCS and make it real to students. Teachers would not have to use it as is, but can adjust".

"Would have like to spend some time using or seeing the electron microscopes used. I did get a picture of it and my students were very intrigued when I talked about it and showed them the pictures".

"It would be useful to include time for teachers to work in teams to develop material (actual lesson plan or parts of them) and then showcase the results".

"I would love to have seen more on the Electron microscope. Possibly even a video of the process to show my students. I know the items being tested were secret, but a video of the process to release after the patent is issued. Also a demo video of the stress tests being performed would be helpful".

"I really liked the idea of the electron microscope. It would be really useful if it were possible to have virtual classrooms set up to use it, talk to scientist etc... about the functions and so forth. Also being able to take a field trip and being able to interact with scientist and engineers would really spark students understanding and growth. I also enjoyed the composite demo. It was very interesting to be able to see the many uses of composites as well as someone break the "airplane wing" with his super human strength ☺ Bill was a wonderful host… extremely kind and very warm and friendly!!!

PS…. I really wanted to hear more about the robotics… but the gentlemen was pretty negative and that was the consensus from our entire group. Perhaps a different speaker would be better for next time to PUMP things up ☺".

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Recommended Site

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