Preliminary Results Regarding 21st Century Content Standards in Physics, Chemistry, and Engineering as Developed by Three Panels of Practicing Scientists and Engineers

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HJR – 25 Subcommittee Meeting
July 16, 2007
Richmond, VA

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Basis for Activity and Objective of Panels

- Activity sponsored through Intergovernmental Personnel Act (IPA) as a partnership for ensuring NASA's next generation workforce capabilities

- Provide "gap analysis" of SOL in Physics & Chemistry and of Virginia's program in Engineering from the viewpoint of practicing engineers and scientists

Panel Philosophy & Composition

- Practicing engineers and scientists drawn from university content-area departments or engineering schools, government research labs, industry, and K-12 (complementary to usual K-12 panels)
  - Covered “A to W” (Astronaut to Weed Science!)
  - Covered full range of technology readiness levels from basic/applied research to technology/development to operations/manufacturing

Logistics

- Nine (9) members on *each* of physics & chemistry panels
- Fourteen (14) members on engineering panel
- Extensive pre-meeting reading sent out 4 weeks prior to meeting
  - VA SOL and Curriculum Frameworks
  - SOL from other leading states (Fordham reviewed)
  - IB, AP, National Science Education Standards, and AAAS Project 2061 (“Science for All Americans” & “Benchmarks”)
  - NRC (National Research Council) and AIP (American Institute of Physics) studies on content of advanced high school chemistry and physics courses
  - Kentucky “Emerging Technology Awareness”
- Each panel met face-to-face for two days at National Institute of Aerospace (NIA) in Hampton

Big Question for Panels

- What (Physics/Chemistry/Engineering) content do 80% - 90% of Virginia's high school graduates need to know to participate in political, social, economic, and technological business of the 21st century?
  - Not about advanced science
  - 10% of 9-12 students are in one or more AP course
  - 1% of 9-12 students are in a Governor's School
  - 0.25% of 9-12 students are in IB programs

- (Also asked Engineering panel what would be appropriate high school preparation for an Engineering major)

STEM Components & Innovation Defined

- **Science** – the ***study*** of the physical world and its manifestations, especially through systematic observation and experiments.

- **Technology** – the application of scientific and engineering knowledge to achieve a ***practical result***.

- **Engineering** – the creation or development of new devices and objects that are of ***importance or value*** to humans and society.

- **Mathematics** – a branch of pure science or philosophy (logic) that in its ***applied*** state can be used to help make quantitative analysis and predictions for science, technology, and engineering.

Innovation – Creation of new ***value***

Example 1:
Humans to the Moon and Safely Home

Need for National Response to Sputnik/Cold War/Missile Gap

Carried out by:

Engineers & many other professions & skills → **Innovation** – Humans to the Moon and Safely Return

Engineers, Technicians & Scientists → **Technology** – Rockets, Protective Clothing, Computers

Scientists & Engineers → **Science** – Newton's Laws of Motion/Gravitation, Chemistry

Mathematicians → **Mathematics** – Algebra, Geometry, Trigonometry, Calculus

Some Preliminary Results – General & Engineering

- **There is no "STEM" program in VA**
  - There is Math (Theory) and Science (Theory) and some Technology (St_M)
  - Engineering is not required for students in VA nor is it generally available to all students.
  - Engineering is book-kept in CTE

- **Engineering Design Process differs from Scientific Method and should be required content in VA**

- **Project Lead The Way (PLTW) is a turn-key national engineering program being taught in 14/134 school divisions in VA and covers almost all that would be needed to learn the engineering design process – ODU is "lead" or "affiliate" university in VA**
  - Ford Motor Company's PAS and TI's Infinity Project also turn-key
  - FIRST (LEGO, VEX, Robotics) projects available (K-12)
  - Children's Engineering Guide is available (K-5) – used in 12/134 VA school divisions

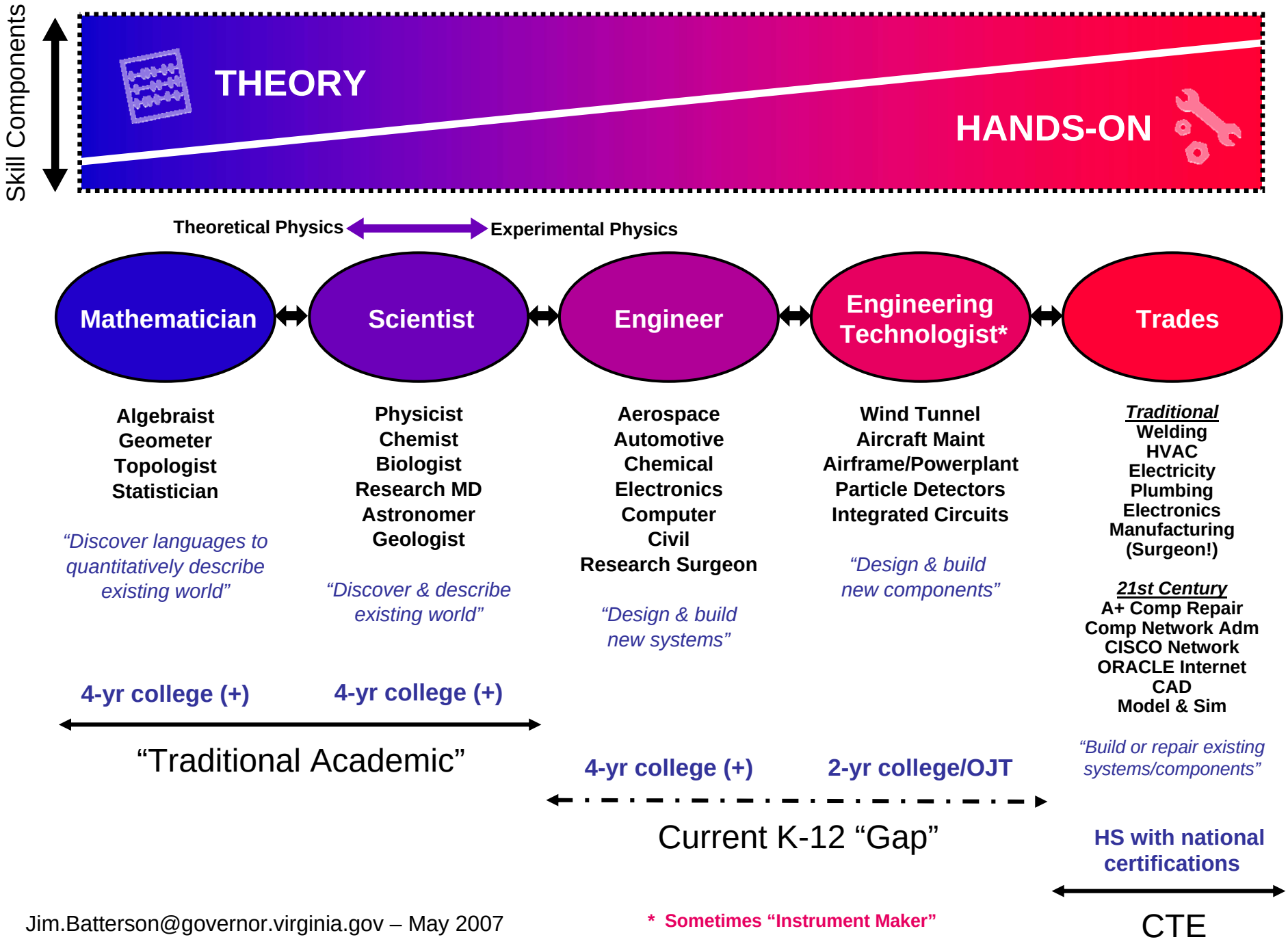
Some Preliminary Results – Chemistry & Physics

- **Laboratories and demonstrations must be integrated into Physics and Chemistry courses and be assessed**
  - Written lab reports required

- **In Physics and Chemistry, panels created "Core" or "Essential" knowledge and "Elective" knowledge with the teacher to choose from among "Elective" subjects**
  - Physics SOL way too broad and miss some more important things
  - Some existing Physics and Chemistry modules can be eliminated or made elective
  - Understanding organic chemistry is essential to life in the 21st century (Molecular Biology).

- **Contemporary applications & emerging technologies of Physics and Chemistry must be taught**
  - Electives: choose from nano, bio, particle physics, superconductors,….
  - DOE should develop and support an open-source wiki for contemporary applications, emerging technologies, and laboratories

- **Consider Leon Lederman's "ARISE" or "Physics First" science curriculum from Fermilab as a total restructuring**



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* Sometimes "Instrument Maker"

Backup Slides

Example 2:
Economic Development and Demographic Expansion

Need for safe and rapid mobility for people & goods (19th C.)

Carried out by:

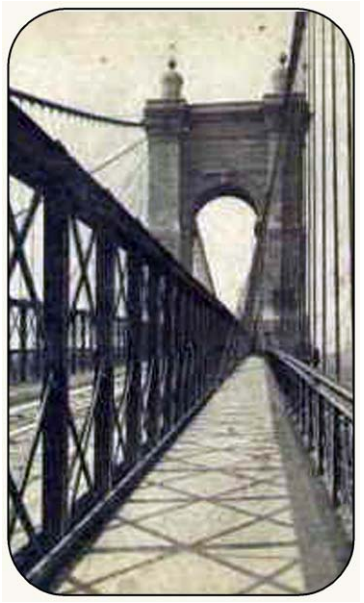
Engineers & many other professions & skills → **Innovation** – Bridges across great rivers

Architecture | *Urban Design*

Engineers, Technicians & Scientists → **Technology** – Iron, Steel

Scientists & Engineers → **Science** – Physics Forces, Chemistry

Mathematicians → **Mathematics** – Algebra, Geometry, Trigonometry



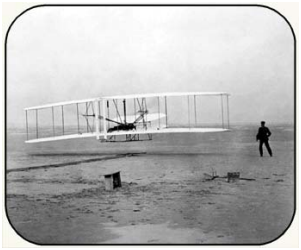
Example 3a:
Air Transportation Vehicle (Practical Airplane)

Carried out by:

Military needs for WW I

Engineers & many other professions & skills → **Innovation** – Curtis Jenny and other practical airplanes

Engineers, Technicians → **Technology** – Wright Flyer (Prototype for a *practical* airplane)



Engineers, Technicians & Scientists → **Technology** – Internal combustion engine, Wind tunnel, Wing warping

Scientists & Engineers → **Science** – Newton's Laws of Motion, Fluids, Chemistry

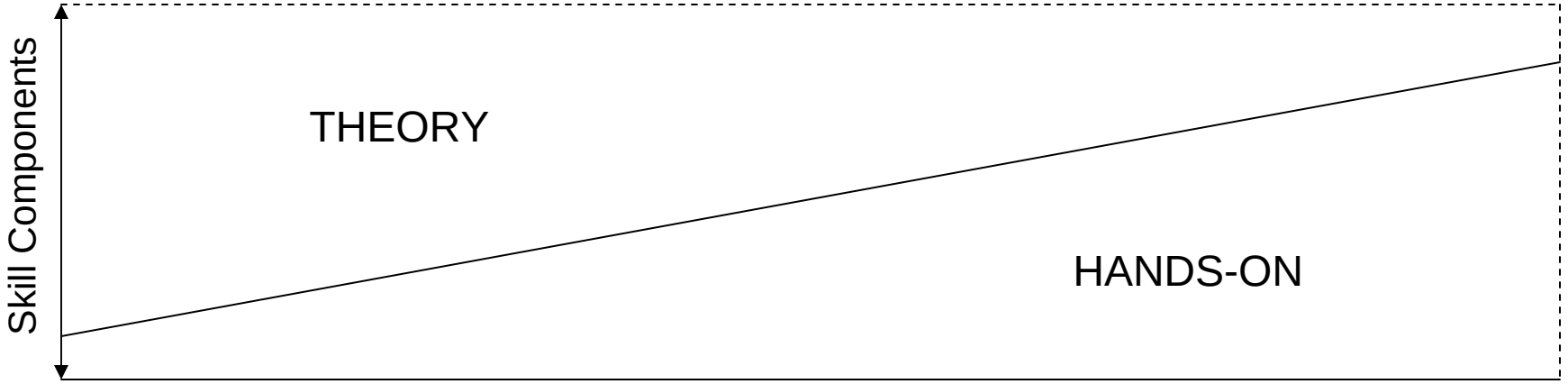
Mathematicians → **Mathematics** – Algebra, Trigonometry, Geometry

Science & Engineering Processes*

A Side-by-Side Comparison

SCIENTIFIC METHOD	ENGINEERING DESIGN ALGORITHM
1. Observe some aspect of the universe	1. Identify the problem or design objective
2. Invent a tentative description (hypothesis) consistent with what you have observed	2. Define the goals and identify the **constraints**
3. Use the hypothesis to make predictions	3. Research & gather information
4. Test the predictions by experiments or further observations, and modify your hypothesis in light of your results	4. Create potential design solutions
5. Repeat steps 3 & 4 until there are (no) discrepancies between theory and/or observation	5. Analyze the viability of solutions
	6. Choose the most appropriate solution
	7. Build or implement the design
	8. Test and evaluate the design
	9. Repeat ALL steps as necessary

* From: “The Infinity Project: Engineering Our Digital Future”



Theoretical Physics ⟷ Experimental Physics

Mathematician ⟷ Scientist ⟷ Engineer ⟷ Engineering Technologist* ⟷ Trades

Mathematician	Scientist	Engineer	Engineering Technologist*	Trades
Algebraist Geometer Topologist Statistician	Physicist Chemist Biologist Research MD Astronomer Geologist	Aerospace Automotive Chemical Electronics Computer Civil Research Surgeon	Wind Tunnel A/C Maint Airframe/Powerplant Particle Detectors Integrated Circuits	21st Century A+ Comp Repair Comp Network Adm CISCO Network ORACLE Internet CAD Mod & Sim
"Discover languages to quantitatively describe existing world"	"Discover & describe existing world"	"Design & build new systems"	"Design & build new components"	"Build or fix existing systems/components"
4-yr college (+)	4-yr college (+)	4-yr college (+)	2-yr college/OJT	HS with national certifications

	Traditional
	Welding
	HVAC
	Electricity
	Plumbing
	Electronics
	Manufacturing
	(Surgeon!)

"Traditional Academic" — Current K-12 "Gap" — CTE

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