

How Tuskegee Could Save the World – and Why We Really Need You

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For more complete detail as of January 2006, email me or go
to www.werbos.com/energy.htm

* Personal, not official views



American Council for
**The United Nations
University**

The Millennium Project

2004 State of the Future

JEROME C. GLENN AND THEODORE J. GORDON

www.stateofthefuture.org



The enclosed CD of over 3,000 pages contains the cumulative work of the Millennium Project since 1996 and details of the studies included in this print section.

CD-ROM
Energy
Paper



National Science Foundation

Engineering Directorate

Computer & Info. Science Directorate

ECS

DMI

IIS

EPDT:
Chips,
Optics,
Etc.

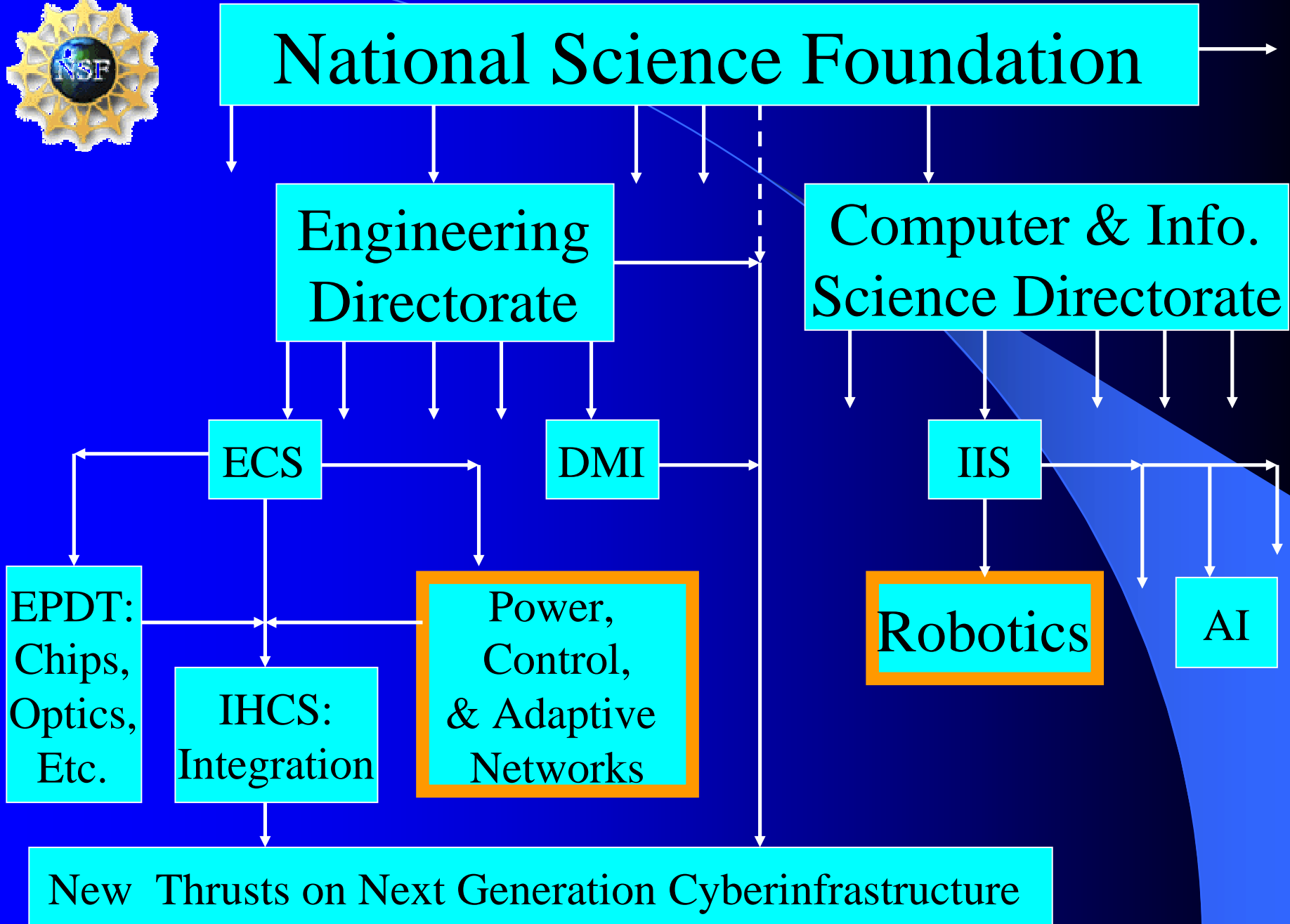
IHCS:
Integration

Power,
Control,
& Adaptive
Networks

Robotics

AI

New Thrusts on Next Generation Cyberinfrastructure

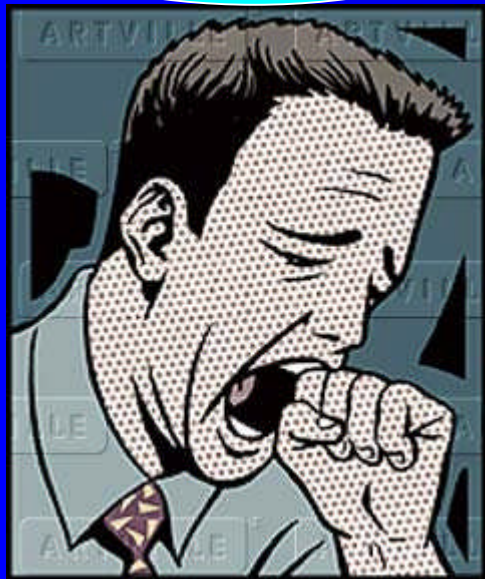


MegaChallenges for the 21st Century & ECS Role

- Key Challenges To Basic Scientific Understanding:
 - How to build/understand systems with truly brain-like intelligence? (computational intelligence)
 - How does the Universe work? (Quantum...)
 - What is Life? (QSB quantitative biotechnology)
- Key Broader Challenges to Humanity:
 - Sustainable growth on earth
 - (e.g. **energy, environment**, water – see www.werbos.com.)
 - Cost-effective sustainable space settlement
 - Human potential

Energy in 2025: It's about People and about Survival, not about oil, + or -

I don't care about 2025.
The whole world could die
for all I care.
I won't be alive then.



Daddy, Please...!
I thought you....



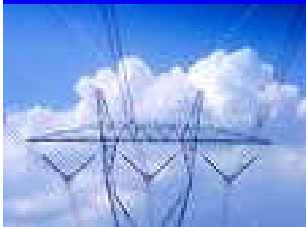
Too bad, kid! He
doesn't really see you.
But he **WILL** feel the
consequences

Truly rational policy analysis never loses sight of the ultimate goal...

3 Linked Big Threats Already Cost us \$ -- We need you to help solve ALL 3!



CAR FUEL SECURITY: Can US economy still work and feed us all if oil is cut off or unaffordable? Is there hope we can pay less for fuel?



DAYTIME ELECTRICITY: Will we have shutdowns if imports of natural gas to US or EU or Latin allies is cut off or unaffordable?



24-HOUR ELECTRICITY: Can we make large scale renewable electricity (solar) cheap enough, soon enough worldwide – before every terrorist cell in the world has material for many bombs & CO₂ ⇒ far worse hurricanes & maybe more snowstorms in Europe, and hunger... ?

How Can We Zero Out America's Need to Import Oil and Gas at the Soonest Possible Time?

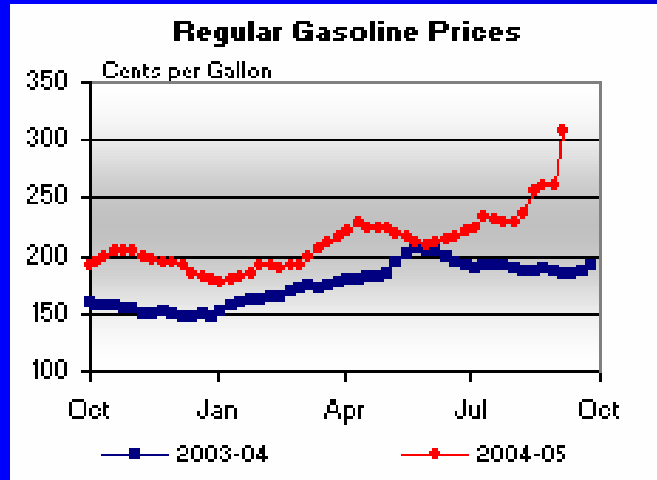
1/26/06: Talk to 200 House of Representatives people, sponsored by office of Congressman Kingston, posted at www.werbos.com..

- Why we **need faster action**. It is literally a matter of life and death – your life and mine!
- How we can do it in the real world of real technology
- No one **on earth** is doing enough yet!

Dr. Paul J. Werbos, personal unofficial views.

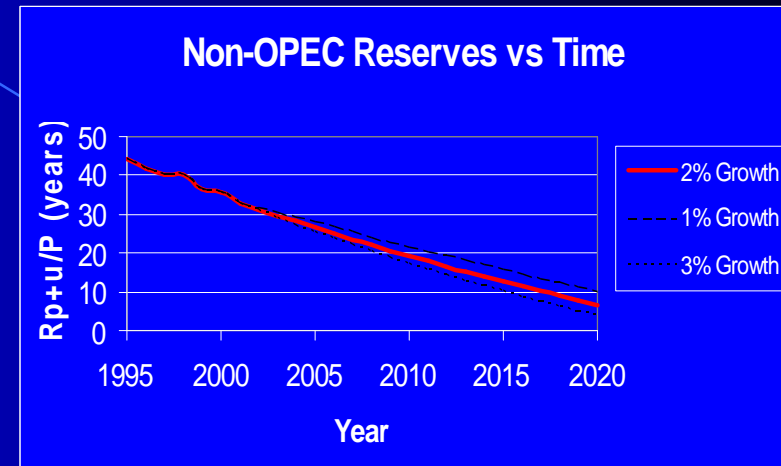
www.nsf.gov/staff/staff_bio.jsp?lan=pwerbos&org=NSF

Why It Is Life or Death



•Source: EIA/DOE

- 1. Gas \$ pre-Katrina already **\$200b/year** > methanol alternative, >> electricity
- 2. Katrina exposed extreme vulnerability. What if it hits Houston next?



•Source: Cavallo of DOE, DHS in BAS etc

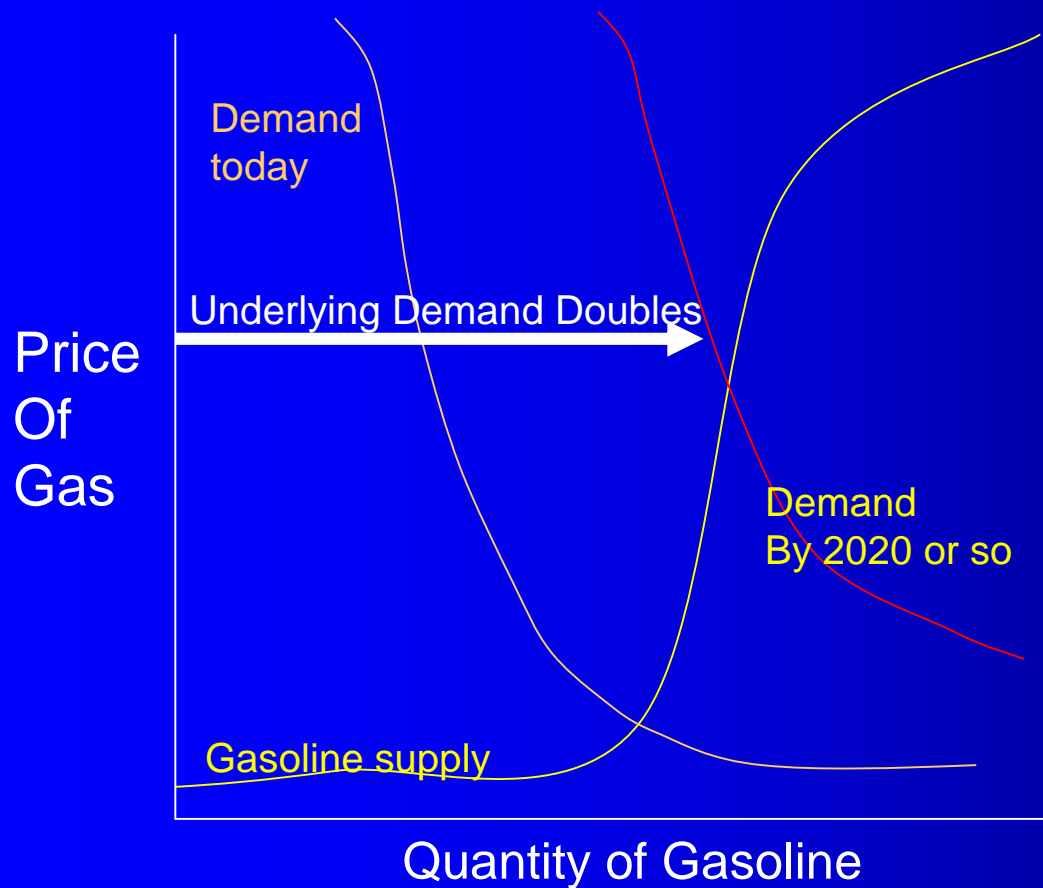
- 3. Peak Oil: Solid projections of 60% world oil imports from Persian Gulf by 2025
- 4. Dependency ↑ + MidEast Conflict ↑ + Nuclear Proliferation ↑ ⇒ Real threat **humans go extinct**

Strong action could change trends now, but would still be barely on time to prevent 2025 disaster!

Rough but Unbiased Guess at What we Pay Today For Fuel Rigidity in Cars

- What would we save if used **methanol** in cars, if US wholesale price of \$220/tonne? (Strong 2004 price).
- 216 b. gallons/yr of gasoline \equiv 418 b. gal. methanol
- EIA Primer on Gasoline Prices: \$1.56 in '03, 14% distribution, 15% refining&profits, 27% all tax
- To \$220/tonne, add same distribution cost cost per physical gallon, same profit and tax per Btu
- At **pre-Katrina** \$2.50/gallon-gasoline, using methanol would have cost **\$324b, versus \$540b!**
- New methanol costs well under \$220/tonne! (Google on “Canaccord methanol”). **Electricity even cheaper per mile.**
- **But: methanol is not the same as ethanol!!!**

How will you cut your gasoline use by 50% or more?



- If output falls, free market raises prices enough to **force** you cut your use in half or more.
- The only question: how? Lower income? Small car? Or market-friendly new technology?
- Antimarket tricks like price caps, hi interest rates, pressures on Arab states only lead to worse outcomes (Nash)

Long-term price elasticity of driving = $-.2$; price doubling Of GASOLINE only gives 14% reduction

A few slides from the (2003) talk which really woke me up to the size of the world energy security problem ---

FUTURES OF THE PERSIAN - ARABIAN GULF REGION

Presented by

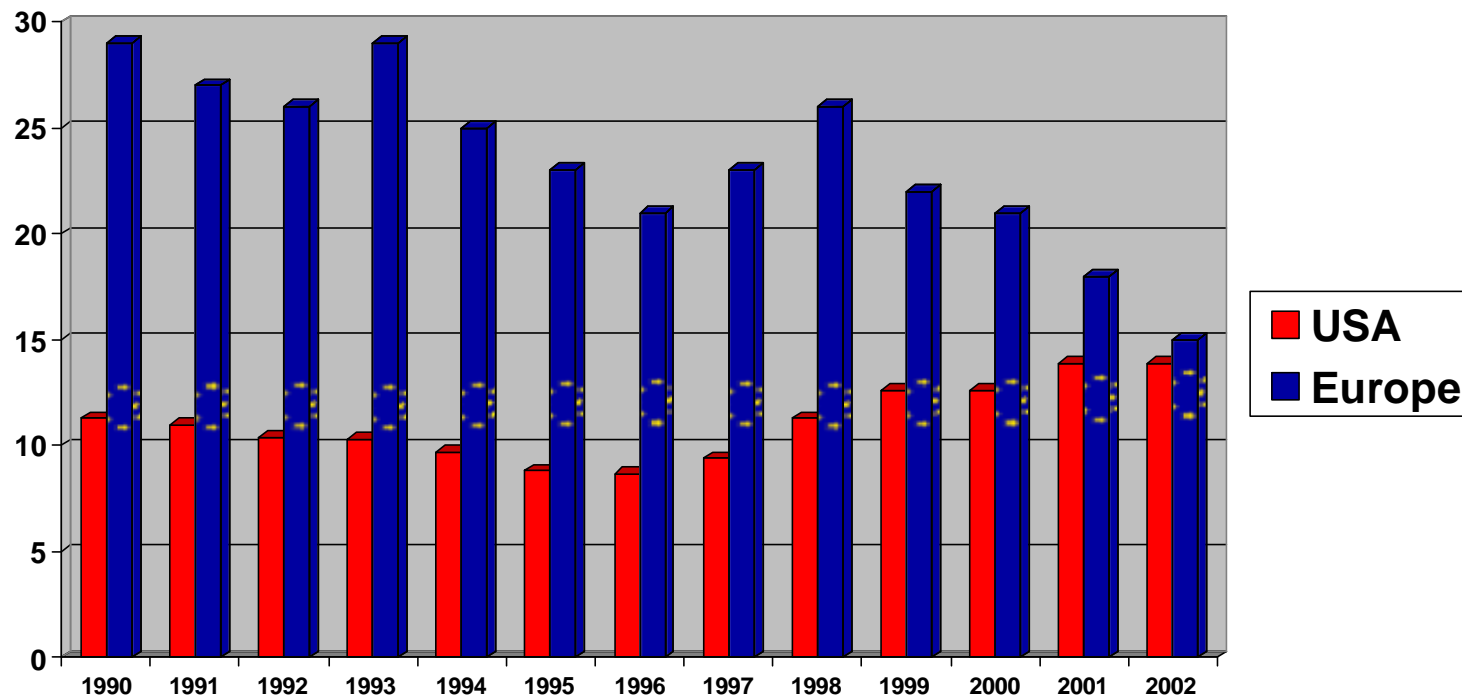
Dr. Ismail AlShatti

President

Gulf Institute for Futures and Strategic Studies

2. CHARACTERISTICS OF THIS REGION

2.3 Potential Influential Power



During last decade exporting oil from the region to USA is increasing whereas exporting to Europe is decreasing. Energy Information Administration has reported that industrial countries will import 72% of their demand from the region and it will be 76% in 2020.

3. SCENARIOS OF THE PERSIAN ARABIAN GULF

3.2 Scenarios of Security and Peace

Escalating the importance of the region for western civilization



The use of oil as a weapon in confrontation between Western and Muslim societies is the main concern of the strategic decision makers in the west. This use will make the military power useless without fuel. It will remain pile of metal scrap.

3. SCENARIOS OF THE PERSIAN ARABIAN GULF

3.2 Scenarios of Security and Peace >> a. Oil Security Track



Where should be the military existence achieved?

This map shows the Oil & Gas field location In Persian Arabian Gulf region and Caspian sea region. The green spots indicates oil field and the red spots indicates gas field. The Green line indicates the oil pipelines and the red lines indicates the gas pipelines. This map gives an idea where the western military existence should be achieved to protect oil field.

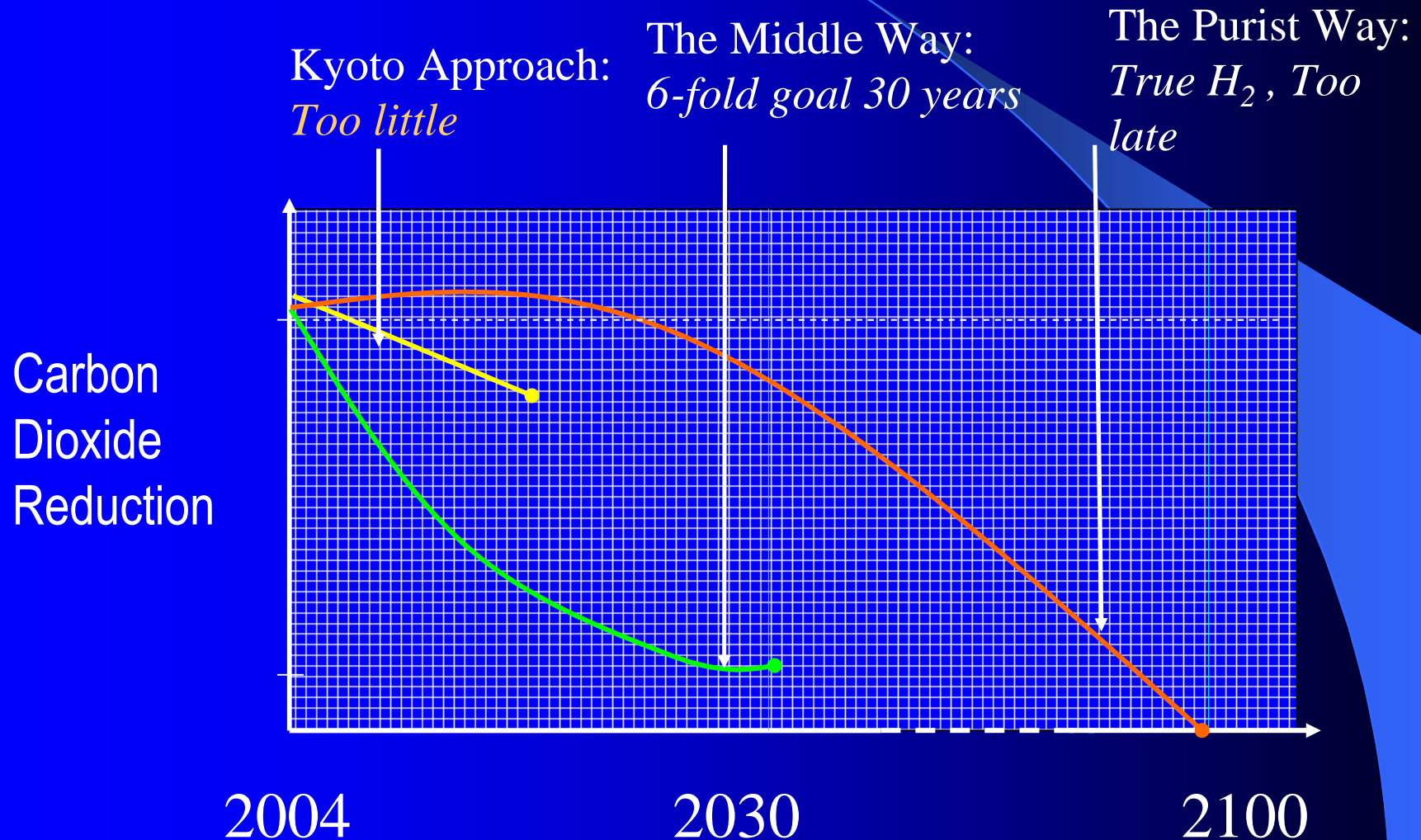
3. SCENARIOS OF THE PERSIAN ARABIAN GULF

3.2 Scenarios of Security and Peace >> a. Oil Security Track



Military existence on the oil fields and multiplying the oil export inlets are not enough for the oil security strategy. Terrorism can hinder the flow out of oil by destroying oil establishments. Military forces are not prepared to fight terrorist groups and gangs. That is why oil security needs political achievements to fill the gaps of this strategy.

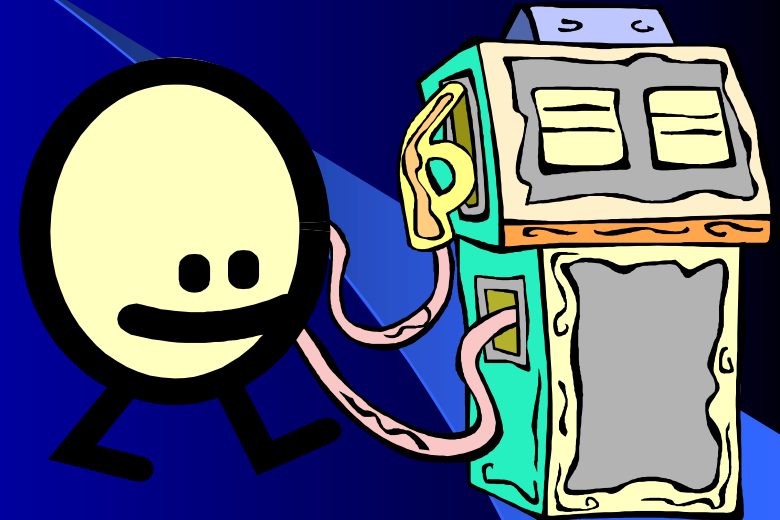
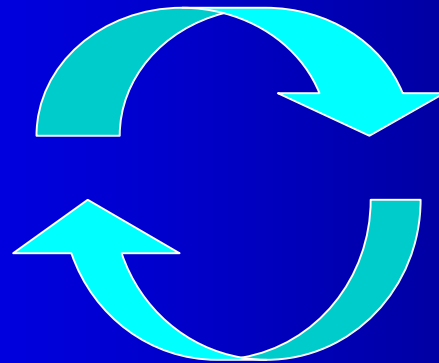
General Strategy: CO₂ As Example of Hard Work But No Solution



Can we Cut our Need to Use Oil and Gas by >50% in 20 years? How?

- How do we keep our **cars running**?
- **The big problem**: the car fleet takes 15 years to turn over. Thus new cars must be >50% gasoline independent **in 5 years** to make it possible.
- Giving up would be crazy – but where is there hope? (But: fuel has more time to catch up.)
- Where does the new fuel or electricity come from? **Sources? Distribution?**
 - **Rapid growth in imports of LNG**
- Serious hope of avoiding a crisis of dependency in time **but no guarantee**

The chicken and egg problem: which comes first? H₂ fuel , H₂ car?

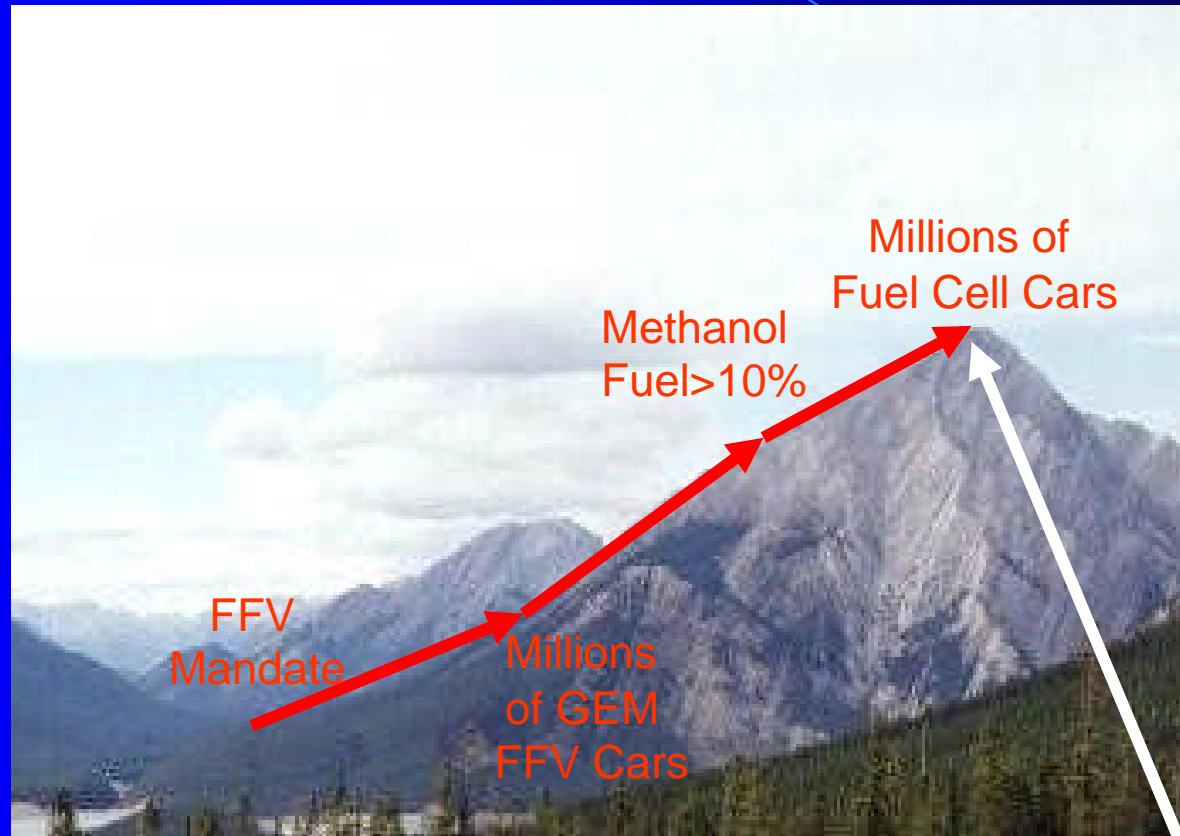


- Would **you** buy a car that only runs on H₂ **before** your local gas station carries H₂? Are PR stations enough?
- Would you invest \$trillion in gas stations and pipelines **before** people have H₂ cars?
- Technically: nonconvexity problem; **also high costs**

Long-Term Clean Alternatives to Carrying H₂ in Your Car Tank

- **Hydrogen Carriers** – proven tested fuels that easily release hydrogen for use on-board a car
 - **Methanol, our best hope** for fuel cells in foreseeable future
 - Ammonia & other carbon-free fuels (but chicken&egg problem again)
- **Electric Cars** – Cleanest, most efficient, but needs R&D; can't yet beat C; new batteries in lab exciting, but not yet... **PLUG-IN HYBRIDS COULD GET US THERE**, but can the US get or make the batteries?
- **Thermal Batteries** – Maybe a better option, becomes possible only after we develop advanced Stirling or Johnson heat-to-electricity technology!

What is the Fastest and Cheapest Way Up Mount Fuel Cell?



FFV
Mandate

Millions
of GEM
FFV Cars

Methanol
Fuel >10%

Millions of
Fuel Cell Cars

Straight Up the
Hydrogen Cliff?

3 Paths to Energy Independent Cars

Areas of US advantage, unused..

Asia leads, rapid growth, US needs to catch up to survive

Hydrogen Fuel Cell Cars with Methanol in the Gas Tank

Stirling or Johnson Cars with "Heat Batteries" to carry energy

True Electric Cars

Flexible-Fuel Vehicles (FFV) able to use methanol

Next-Gen Stirling Engine or JTEC/hybrid Car

Plug-In Hybrids: Hybrid+10kwh battery, Goes 30 km on battery

FFV law: open standards for fuel

More, Better Production of Batteries, SiC etc.

More SOA Hybrids

Plug-in Hybrids: A Large-Scale Opportunity Here and Now

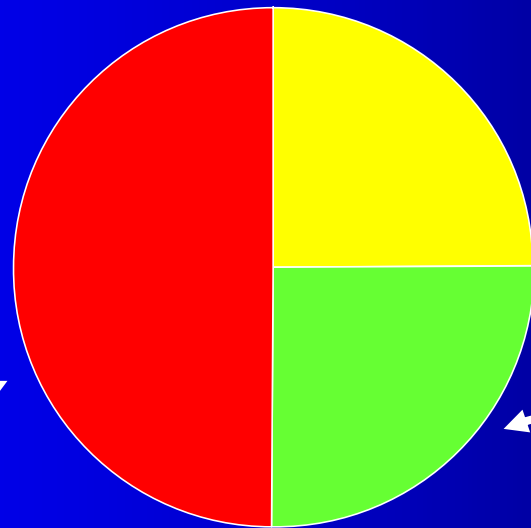
- FFV hybrids cut liquid fuel use 50% already. Plug-ins cut **50% of that**.
 - “Researchers have shown that (batteries) offering.. electric range of 32 km will yield... 50% reduction..” (IEEE Spectrum, July/05). Shown in working Prius.
- Battery **breakthroughs in China**: from 10/07, 10kwh batteries (larger than) cost **\$2,000**. www.thunder-sky.com. Thus an extra \$2,000 per car can cut gas dependence in half.
- Gives economic **security** in case of sudden gasoline cutoff.



How To Zero Out Gasoline:

Best Near-Term Hope for 100% Renewable
Zero-Net-CO2 cars & Zero Energy Imports

Best Advanced
Hybrids Cut
Gas per Mile
By 50%



With **GEM fuel-flexible** cars,
biofuels might supply $\frac{1}{4}$
of present liquid fuel
demand trends

Plug-in Hybrids
with 10kwh batteries
get half their energy
from electricity

Superflex: GEM fuel-flexible hybrid cars offer a
100% solution based on near-term technology!

To The Rescue: Lonnie G. Johnson

- Founder and President
- NASA (Voyager, Mars Observer, CRAF, Cassini, Galileo)
- Holds over 90 patents
- B.S. in Mechanical Engineering, Tuskegee University
- M.S. in Nuclear Engineering, Tuskegee University
- Ph.D. (Honorary) in Science, Tuskegee University
- Projects relying on Tuskegee labs and students



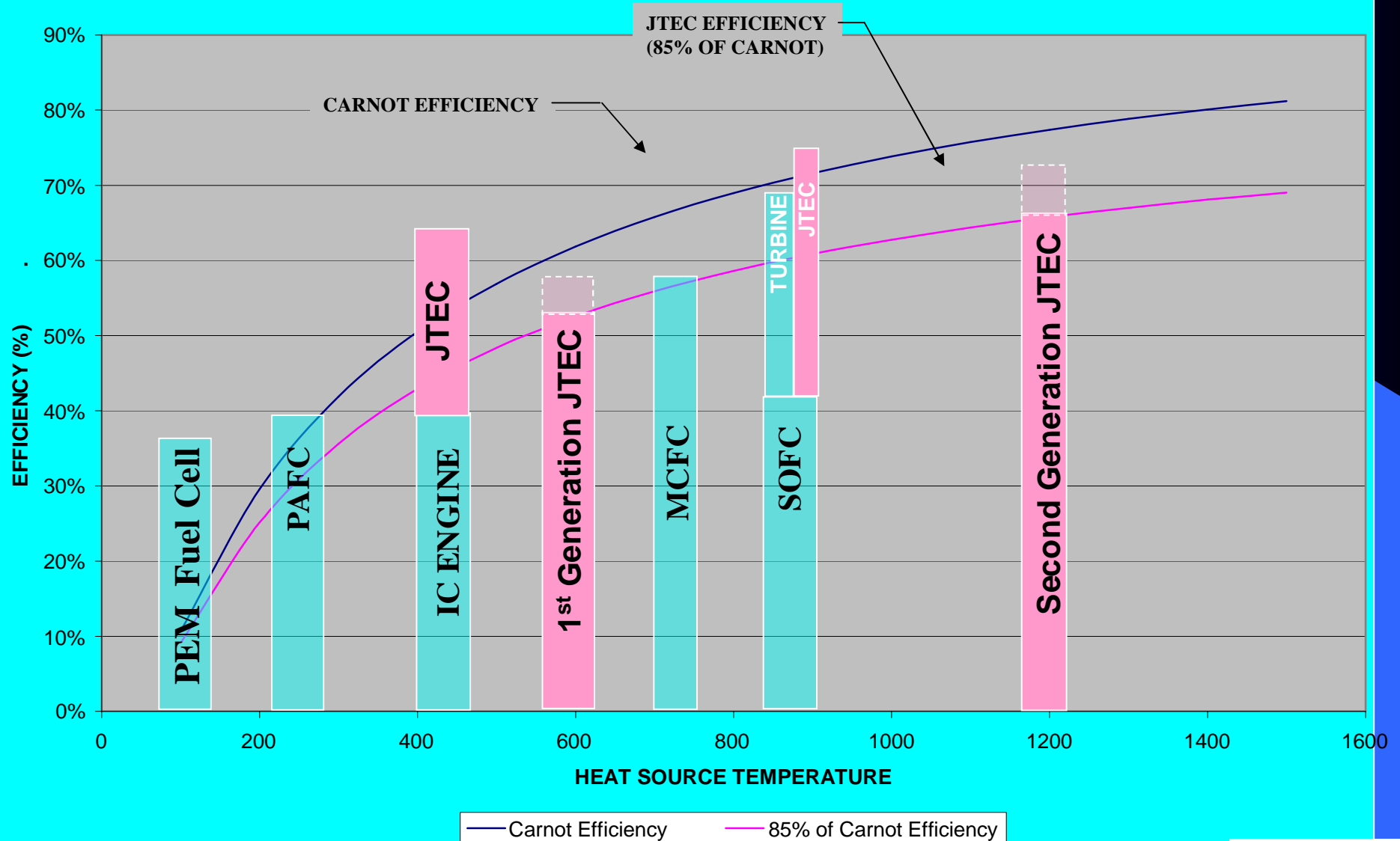
*“One of the Top Inventors in
the World”*

Time Magazine

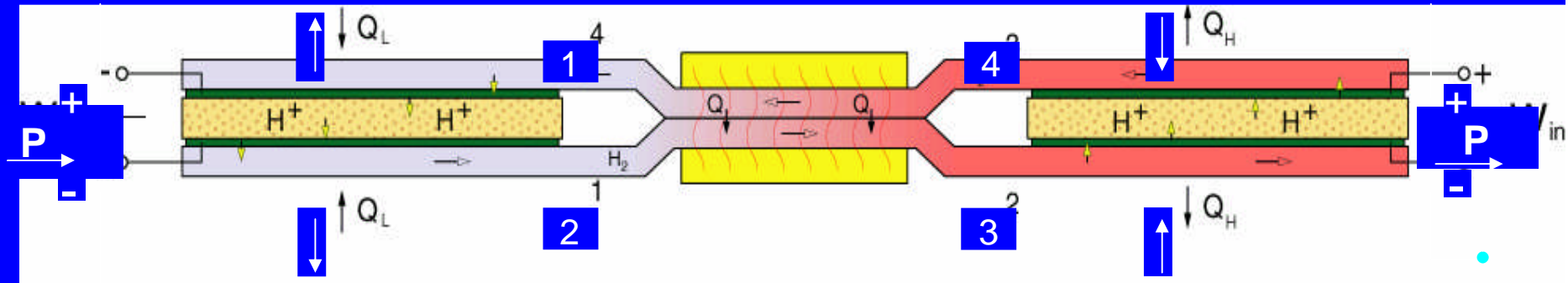
Exciting credible new ideas (risky but near term) for US to leapfrog the world both in batteries and in more efficient heat-to-electricity for flexible cars !!!!!!!

If JTEC works, we **don't need fuel cells** for cars & can use **any fuel!!!**

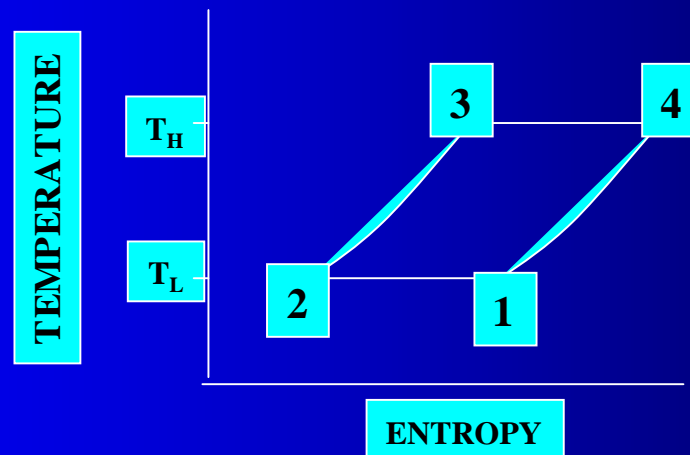
Chart In: **EFFICIENCY OF FUEL CELL/ENGINE SYSTEMS**
HEAT SINK TEMPERATURE = 60°C



JOHNSON THERMO-ELECTROCHEMICAL CONVERTER (JTEC) -- Patents Pending

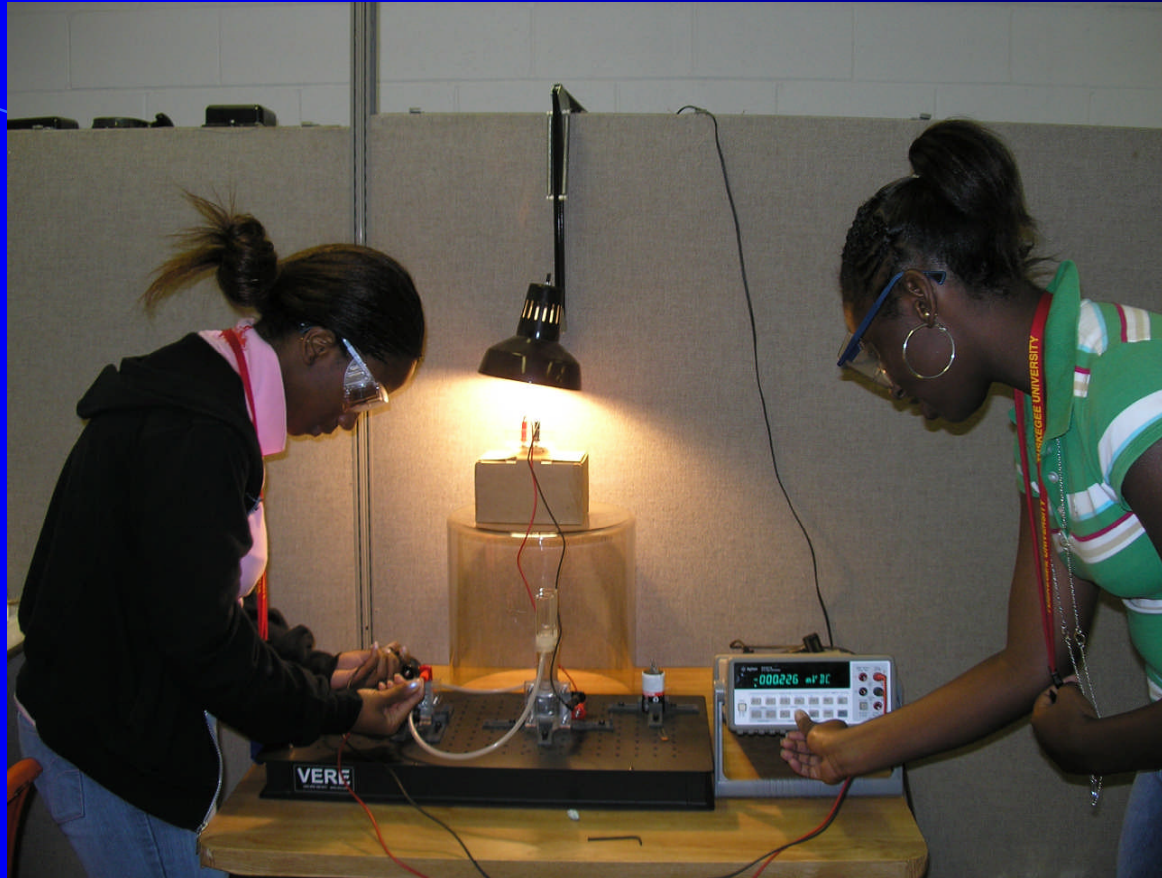


TEMPERATURE ENTROPY DIAGRAM FOR ERICSSON CYCLE



Not a heat-to-electricity chip! Not a heat engine to make heat to go to a generator!
A fundamentally new way to go from heat to electricity, grounded in basic science!
But it all depends on new membranes. Who could provide such membranes?...

Here's who: the laboratory of Prof Aglan at Tuskegee University!



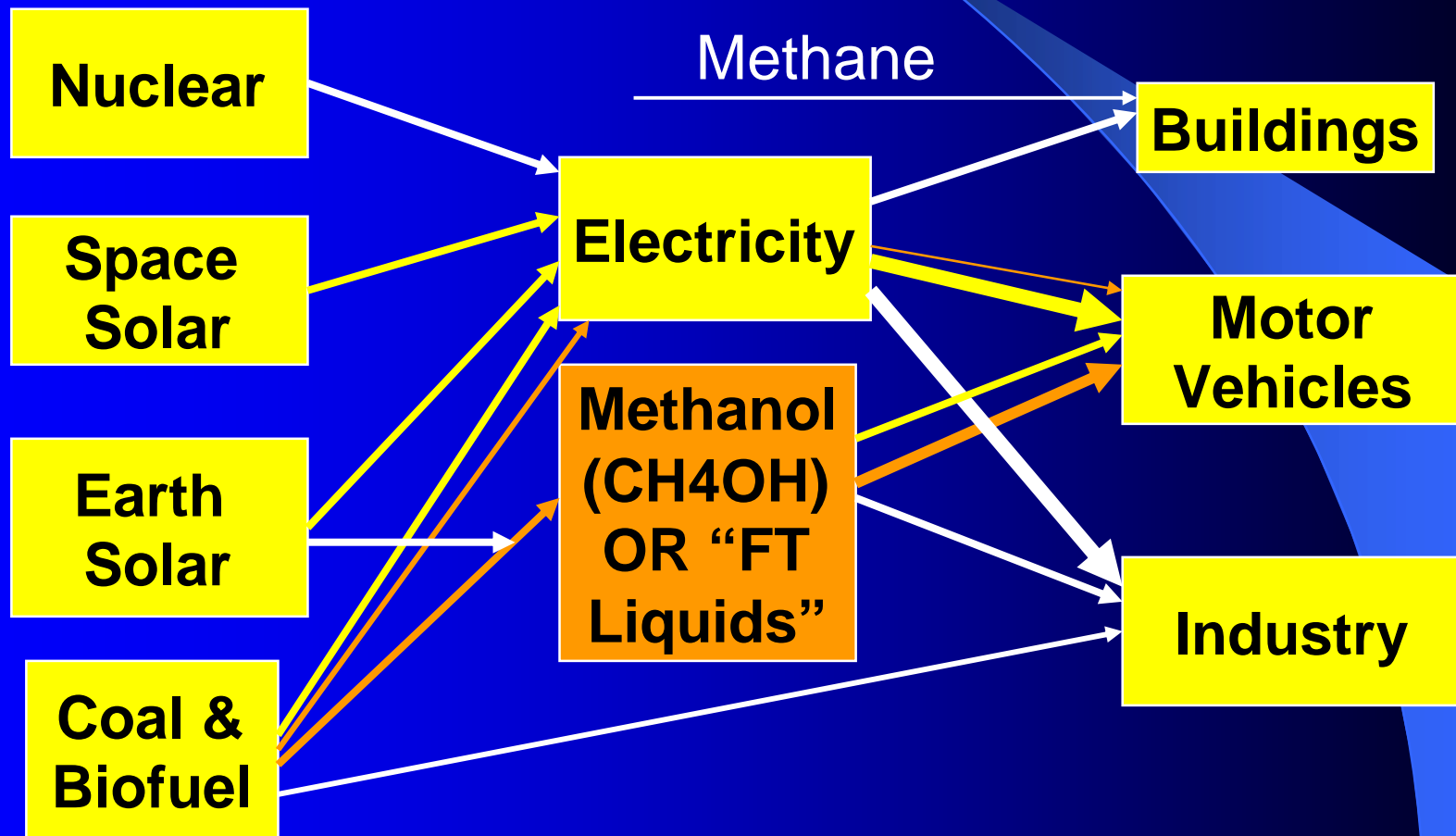
Summer school students changing the world –
but we really need more of you!!

Batteries Too: Two New Concepts to Use Those Membranes to Outperform Asia on Batteries for Plug-in Hybrids (Maybe Even Affordable True Electrics!)

| | Specific Energy (Wh/kg) | Energy Density (Wh/l) | Discharge Rate (C) | Specific Power (W/kg) | Cycle Life |
|----------------------|-------------------------|-----------------------|--------------------|-----------------------|------------|
| Nickel Cadmium | 80 | 150 | 10 | 500 | 800 |
| Nickel Metal Hydride | 150 | 250 | 5 | 200 | 800 |
| Lithium ion | 211 | 577 | 5 | 300 | 500 |
| DMFC | 250 | 75 | 5 | 500 | 500 |
| Johnson Lithium Air | 2000 | 2000 | 5 | 400 | 500 |

Note: Lithium ion represents best state of the art today. Johnson Lithium Air is one of two new concepts, also relying heavily on new membrane technology, seen by gov't but proprietary.

But where do we get the electricity
(or heat) for these new cars, as
oil & gas become too expensive?



Sources: Where Does the Electricity or Methanol Come From If Not Oil/Gas?

- Two scenarios: Base-Case-Present-Trends Versus Real-Hope-If-We-Act-More
- Base Case:
 - Iran, China, eventually everyone builds fission as fast as they can. Bin Laden Construction Co. and its less savory competitors grow very rich, very fast. 4-8¢/kwh
 - Little guys (wind, rooftop solar, Anwar, ethanol) make big \$ but don't plug half the supply-demand gap
 - Supply-demand gap still widens. Old coal fills the gap, filling half the world with barely survivable air (worse than China's cities today). Not so much methanol.
 - “Santa Claus drowns” Arctic Ice Cap Double or Nothing

Real Hope If We Work/Think Hard

- **THREE TEAM A TECHNOLOGIES**

- We know that all three CAN WORK and CAN provide all the world's energy needs cleanly
- “IGCC” (Cool Water/Texaco/Eastmann/GE) **Clean Coal** Technology, Good for carbon sequestration, efficiency, wants to produce electricity and methanol together. But: how fast can we ramp it up? Technology to dispose of CO₂ not yet good enough.
- **“solar farms” on earth with mirror or lenses:** but breakthru needed on cost...
- **24-hour energy from space** – new designs from NASA-NSF-EPRI offer a path to beating coal nuclear on cost with great hope of success...

- Need better (agile, international?) funding vehicle for high risk breakthrough TEAM B hopes, in diverse new areas as they arise...

Earth Solar: New Opportunity for Cheap Renewable Daytime Electricity

- DOE 10-year targets: **14¢/kwh** PV, intermittent power, can't compete with coal 4¢ baseload. Cost of “balance of system” is stubborn with solar farms -- & worse for low efficiency (now 3%) “nano-based” PVs this decade. World Bank (GEF): solar thermal “Luz” still **12¢/kwh**.
- Recent breakthrough: Business Week (9/12/5) reports SES unsubsidized sale of 500 megawatt Stirling/dish farm to SCE, “well under” today's **11¢/kwh** – probably near Sandia's **6¢/kwh** estimate. **Mojave enough for all US**.
- Inventor of that engine plus former GM DD for Advanced Products have credible plan to cut that cost in half – **as yet unfunded**. High-efficiency heat to torque or kwh also useful in space nucs, cars, etc. Scales to 50kwh: could provide cheap **secure electricity to sunny DOD bases!** Reduce EU dependence on Russia, Chile's on Bolivia?
- **New project:** Chile, inventor, GE, Ga Tech for hookup...

But if/when JTEC Works, We Can Do Even Better!



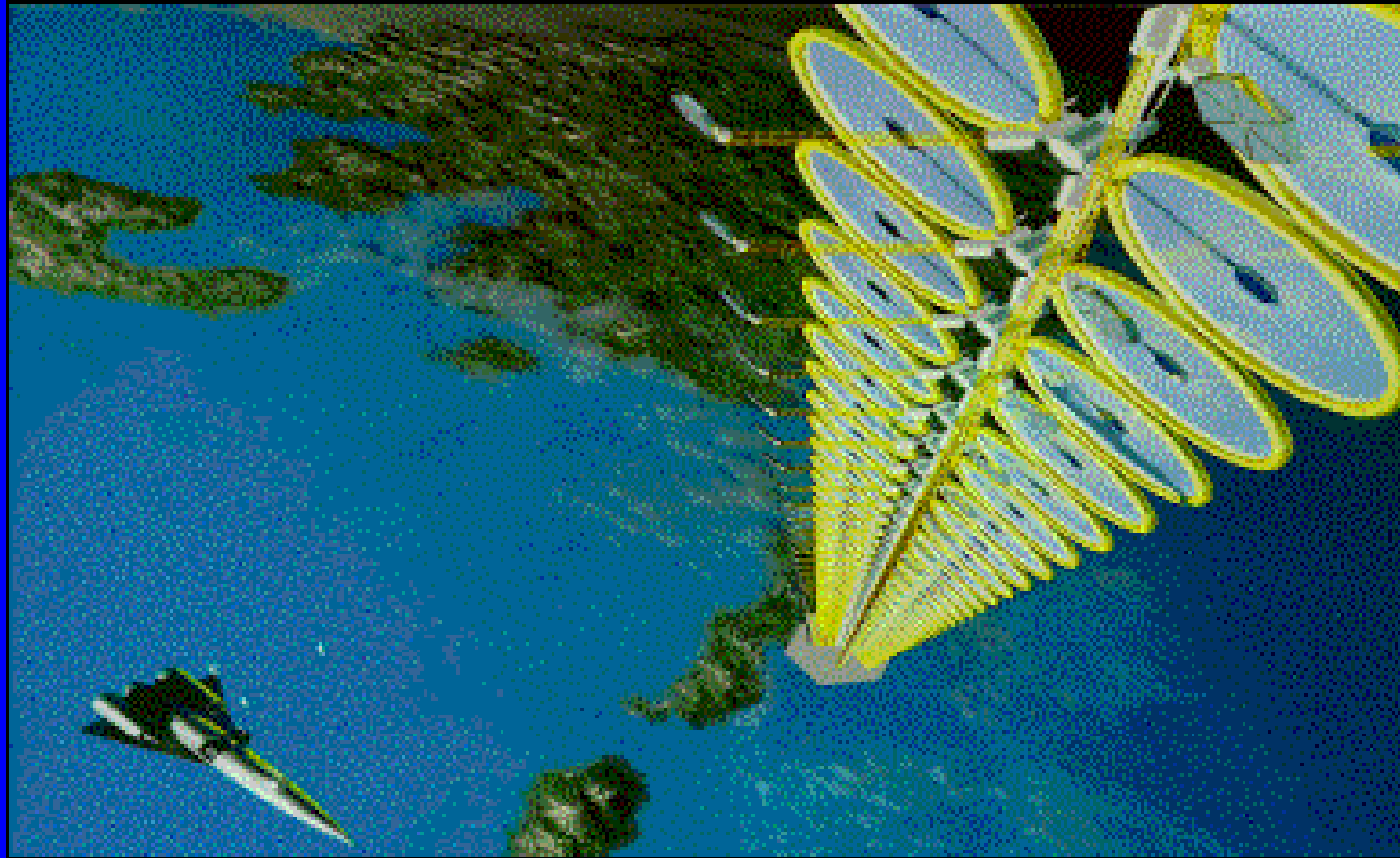
- Plug in JTEC instead of Stirling to get more electricity from the same heat with the same type of new reflector! More electricity at same system cost would imply **even less than 4¢/kwh!**



- The same NSF-funded work from Georgia Tech could cut the cost of the grid hookup, if fully developed/funded/etc. !



NSF-NASA Workshop on Learning/Robotics For Cheaper (Competitive) Solar Power



See NSF 02-098 at www.nsf.gov & URLs
Joint funding led by Werbos/NSF & Mankins/NASA



Some Outcomes

- 98 proposals, \$21 million recommended after tough merit review, \$3 million funded
- Previous NASA SERT program: first **well-validated designs** but 17¢/kwh even assuming \$200/lb earth-to-LEO (Low Earth Orbit)
- Now 4 designs may achieve cost breakthroughs, merit follow-up. One – hybrid light-to-light laser with D-D inertial fusion and microwave beaming might get well under **1¢/kwh** for kwh at central point in space.
- Little of Texas A&M claims he can demo ability to avoid communications interference. Current designs cost about **4¢/kwh just to get power from space to earth grids**, but many believe this could be cut a lot with new R&D.
- “Near-term vehicle” design 1st wi real hope <\$200/lb

Four ~New Lo-Cost SSP Designs

- Mankins' new version of solar cells to electricity to microwave
- Fork/Werbos (TIM 2002) “spinal cord” laser, light lenses/mirrors to **light-to-light laser** to earth
- Werbos **solar/fusion hybrid** lenses, laser, D-D pellets
- Nonterrestrial materials (**NTM**)
 - Idea not new; **Gerard O'Neill & Criswell** still vital
 - Engineering needs major fleshing out, testing, multiple iterations etc. Lower TRL than the others, but high potential and relevance to President's Program
- All designs require a flexible “decision theory” vision
 - Need honesty and toughness about uncertainty to **make it real**

Key Needs for Energy From Space

- New Big Laser (2/4 cheap ways)
 - Heat dissipation (Johnson heat pipe idea) is one of the crucial design/cost drivers!!
 - Earth based research here is the most critical element to find out and minimize ultimate cost of electricity
- Affordable launch (follow-on to ECS-funded plasma hypersonics – requires US proprietary technology, \$10-15 billion)
- Improved Robotics – **REQUIRES MORE USE OF COMPUTATIONAL INTELLIGENCE!!!**
(NSF/DARPA??)
- Cheaper power beaming – PES/MTT partnership

Plasma Hypersonics: ANSER/Chase NSF\$

REDUCED DRAG: AAC 1st; Ganguly (APS00) shows it should work $>$ Mach 4, 100K feet; allows Boeing RAS/V



Ebeam
or

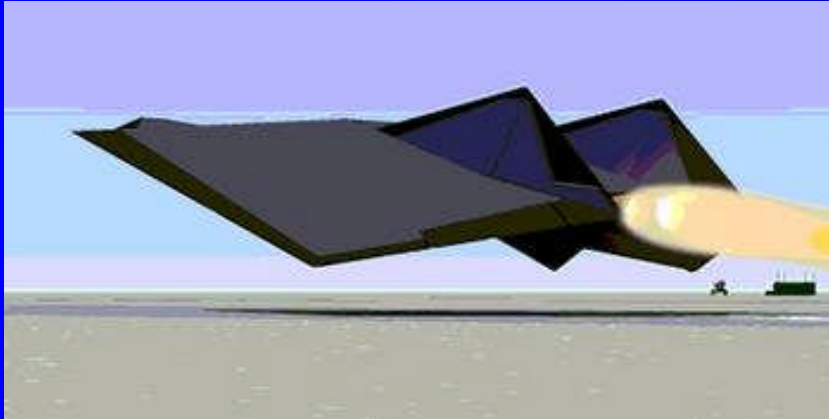


MHD Energy
Extraction

MHD
Acceleration

Best plasma theory predicts new Princeton design will allow ramjets to reach Mach 12, scram much more...
Ames and Chase (ANSER) whole-system SSTO designs..

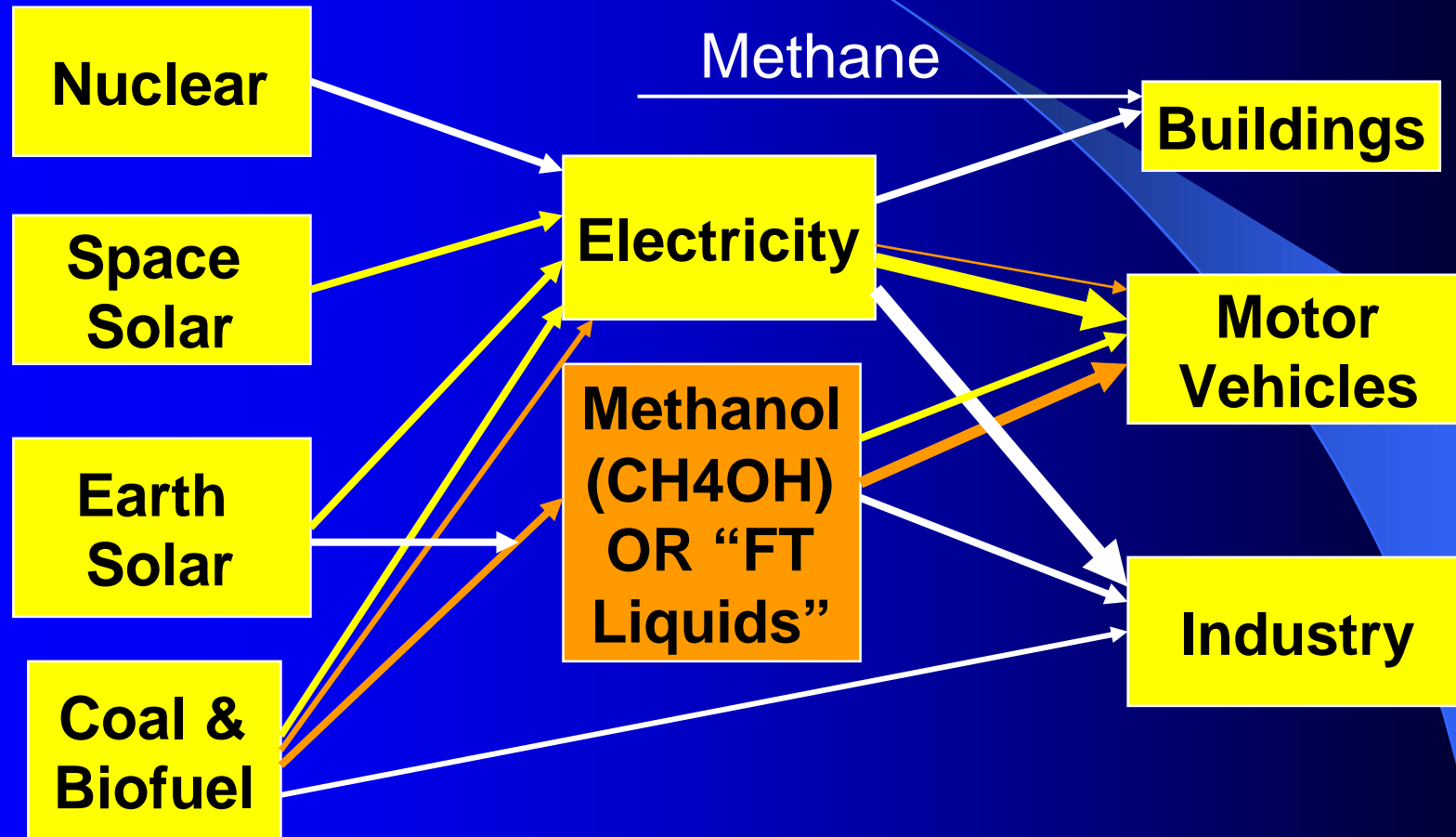
Unexpected Outcome: Near-Term Design Has Passed Tough Peer Review, Scrutiny



Rocketplane RLV can be built **now** for near-term use, **essential** to use/enhancement of **endangered** off-the-shelf legacy technology needed for more advanced high-efficiency concepts

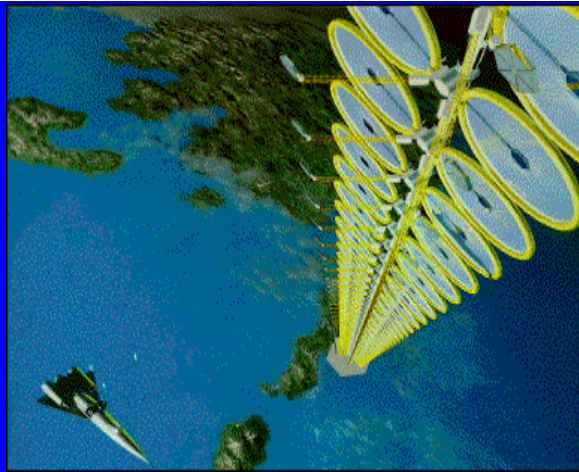
- **Urgent need** for \$30-150 million structures project to avoid losing (\$30m) or to update (\$150m) CIA-legacy technology & revive \$1m study to NSF/NASA
- Need Big vehicle to minimize \$/lb (initial \$200/lb **REAL**)
 - 1.2 million pounds, \$10-15 billion, **not a small business**
- **Horizontal takeoff essential** for aircraft operations (see also Mueller 60's) and for big-wing lower heat load on re-entry
- Design allows use of formerly black **hot structures technology** instead of flaky tiles, ablative structures, hard-to-control slush
- Project chart **4 years**, AF mission model enough for profit

Distribution and Grids: Upgrading the Middle is Also an Essential Driver of the Economics!



**Adaptability & Intelligence in the Electric Power Grid
Could Be a Big Help in Adapting to New Realities!**

Why It is a Life-or-Death Issue



HOW?



2 Hour Tutorial Given in
China May 2006

•Photo credit IEEE Spectrum

As Gas Prices \uparrow Imports \uparrow & Nuclear Tech in unstable areas
 \uparrow , **human extinction** is a serious risk. Need to **move faster**.

Optimal time-shifting – big boost to rapid adjustment, \$

Why It Requires Artificial Neural Networks (ANNs)

- For optimal performance in the general nonlinear case (nonlinear control strategies, state estimators, predictors, etc...), we need to adaptively estimate nonlinear functions. Thus we must use **universal nonlinear function approximators**.
- Barron (Yale) proved basic ANNs (MLP) **much better** than Taylor series, RBF, etc., to approximate smooth functions of many inputs. Similar theorems for approximating dynamic systems, etc., especially with more advanced, more powerful, MLP-like ANNs.
- ANNs more “chip-friendly” by definition: Mosaix chips, CNN here today, for embedded apps, massive thruput

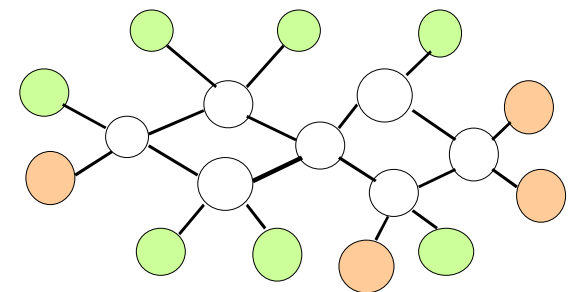


Dynamic Stochastic Optimal Power Flow (DSOPF): How to Integrate the “Nervous System” of Electricity

- DSOPF02 started from EPRI question: can we optimally manage&plan the whole grid as **one** system, with foresight, etc.?
- Closest past precedent: Momoh’s OPF integrates &optimizes many grid functions – but deterministic and without foresight. UPGRADE!
- ADP math required to add foresight and stochastics, critical to more complete integration.
- New work may deeply cut cost of hooking up solar (e.g. JTEC!) to electric power grids. Can we get do enough to get GE or ABB to follow through?



ANN to I/O From Idealized Power Grid



- 4 General Object Types (busbar, wire, G, LI)
- Net should allow **arbitrary number** of the 4 objects
- How design ANN to input and output FIELDS -- variables like the SET or values for current ACROSS all objects?

Beyond Bellman: Learning & Approximation for Optimal Management of Larger Complex Systems

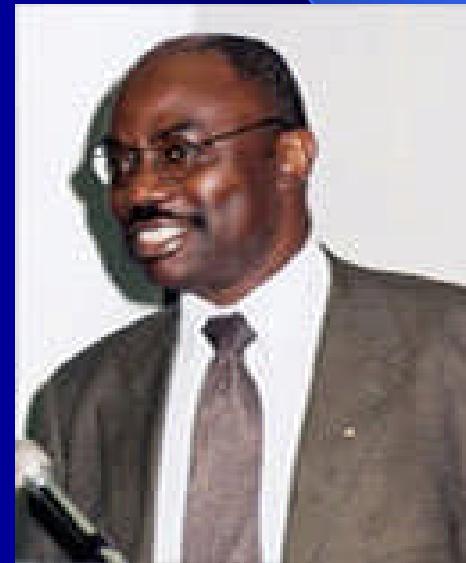
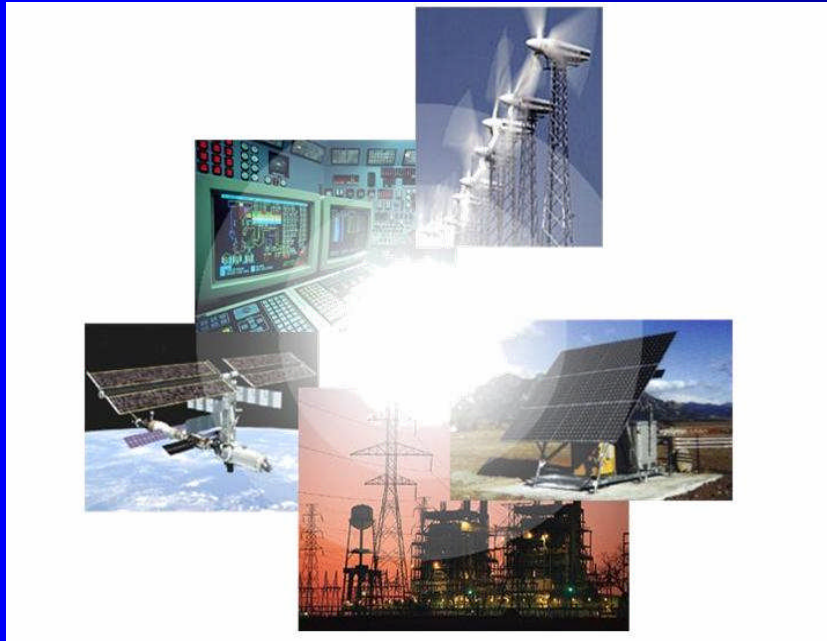
- Basic thrust is **scientific**. Bellman gives exact optima for 1 or 2 continuous state vars. New work allows 50-100 (thousands sometimes). Goal is to **scale up in space and time** -- the math we need to know to know how brains do it. And unify the recent progress.
- Low lying fruit -- missile interception, vehicle/engine control, strategic games
- Workshops: ADP02 ebrains.la.asu.edu/~nsfadp, & Dynamic Stochastic Grid testbed; ADP06 April 2006

Intelligent Grid Requires Intelligence But Also Hardware

- Brain-like intelligence is **embodied intelligence**; sensors, actuators and feedback on performance are essential parts of the new designs.
- Reduce world CH₄ to kwh: **sell and upgrade** Brazil's superior transmission technology (Pilotto, Watanabe: could save California billions quickly, allow cheap electricity from underused Utah coal plants)
- **EPRI plan** to add more communications, sensors, intelligent appliances (e.g. car chargers to turn on at quiet times at night, to exploit times of strong wind)
- Interface of intelligent grid with human users, markets and regulations. (www.pserc.cornell.edu; "EPNES" at www.nsf.gov.)

For More Information on DSOPF or
brain-style intelligence, see
www.eas.asu.edu/~nsfadp

See the Handbook Chapter on DSOPF by
James Momoh of Howard University...



www.cesac.howard.edu