

Opportunities For New World Leadership in S&T – Unmet Global Opportunities & Lessons From The Trenches

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Which Trenches?

- Governing or Advisor Boards
 - ACUNU Millennium Project (MP)
 - International Neural Network Society (Past President)
 - IEEE Computational Intelligence Society (& Pioneer Award for *the* most widely used algorithm), Industrial Electronics Society, Energy Policy Committee, previously Systems, Man, Cybernetics
 - International PostGenomics Society
 - National Space Society
- Front-line funding and management of projects
 - Energy 79/89, built top econometric models, lead for long-term
 - National Science Foundation
 - Core: Adaptive & Intelligent Systems; Quantum, Molecular and HP..
 - Fuel/Cell Electric Cars, wireless, cyber, electric power, collaboration for computational neuroscience, space solar power, quantitative systems biotechnology, emerging technology, education, MUSES...
 - Patents, IntControl

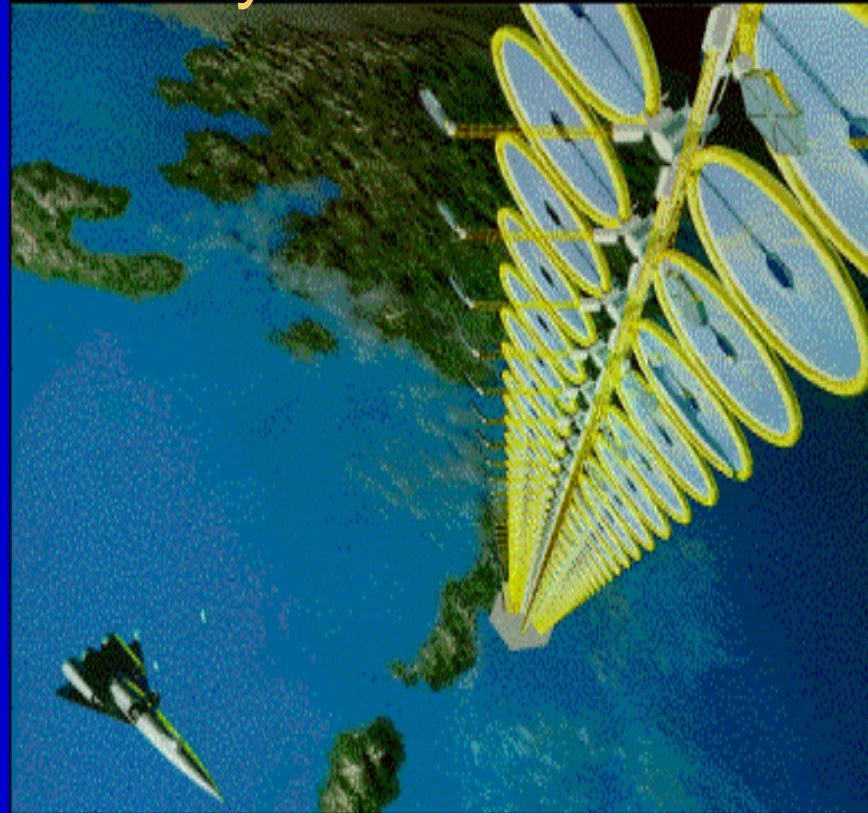
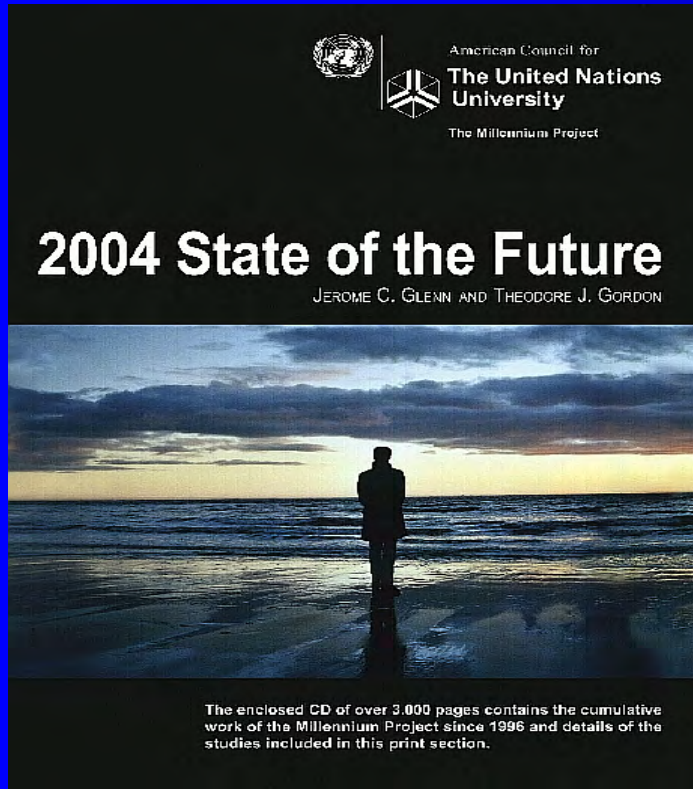
Si'an Kaan, Sacred Tree of Mayas



Pervasive Themes:

- We need to grow a healthier link between airy high level vision and muddy reality, supply and demand, serious global futures and solid foundations
- Don't sell mud pies
- Strategic thinking requires **thinking**

Example 1: MP S&T Study asks world policy makers:
What could S&T do of greatest value to future of
humanity?



#1 response: nonfossil nonfission world-scale 24-hour energy source (CO2, proliferation)
Follow-on: NASA-NSF initiative on energy from space, risky but best hope. Breakthru designs badly need international follow-on

Example 2: A Popular Vision of Future S&T

Foundation & Critical Enabler: Intelligence

Info/Cogno Tech

Convergence?

BioTech

NanoTech

Foundation:
What is Life?
Math of Self-Organization

Foundation:
Basic Laws of Physics
Quantum-Classical Equivalences

&: Converge in Foundations or Just Wires in Head?

6 MegaChallenges for the 21st Century

- Key Challenges To Basic **Scientific Understanding**:
 - What is **Mind**? (how to build/understand intelligence)
 - Basic Science of Mind: Up To the Highest Kind of General Intelligence We see in the Smallest Mouse
 - Middle Sci. Mind: from Mouse to “Sapient,” the level of full use of symbolic reasoning integrated with meaning/empathy (human brain is “new”, still halfway there in its evolution)
 - Higher Sci. of Mind: Principles of higher levels in intelligent systems design, like quantum, multimodular, soul
 - How does the **Universe work**? (Quantum physics...)
 - What is **Life**? (e.g., quantitative systems biotechnology)
- Key Broader Challenges to **Humanity**:
 - **Sustainable growth** on earth. Sustainability means “change or die.”
 - Global sustainable **energy/environment** & mid-term survival
 - “**yin sustainability**,” e.g. population, related women’s issues, peace
 - Cost-effective sustainable **space** settlement
 - Human potential -- growth/learning in brain, soul, integration (body)

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?

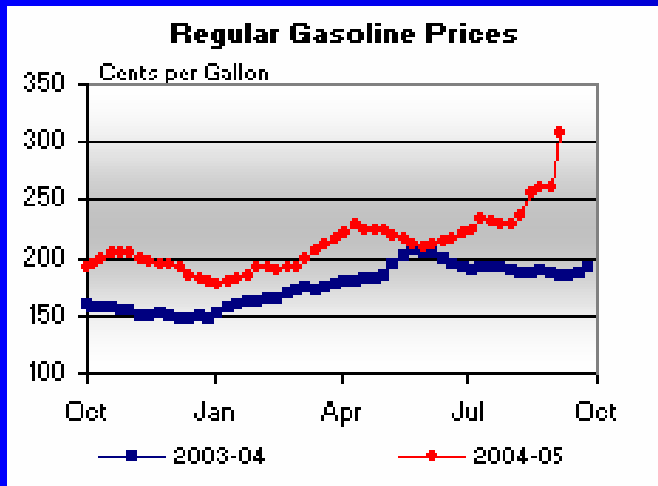
1/26/06: Talk to 200 House of Representatives people, sponsored by office of Congressman Kingston, posted at www.werbos.com..

- 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!

The same issues apply to all nations which depend on oil imports

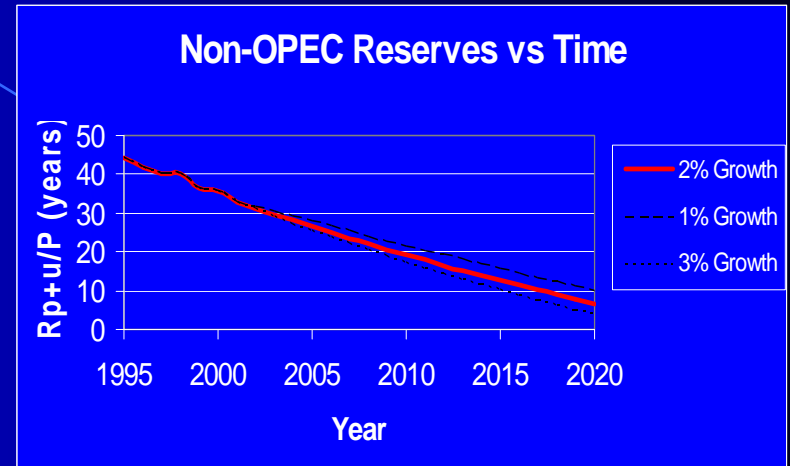
Dr. Paul J. Werbos, personal unofficial views.

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?

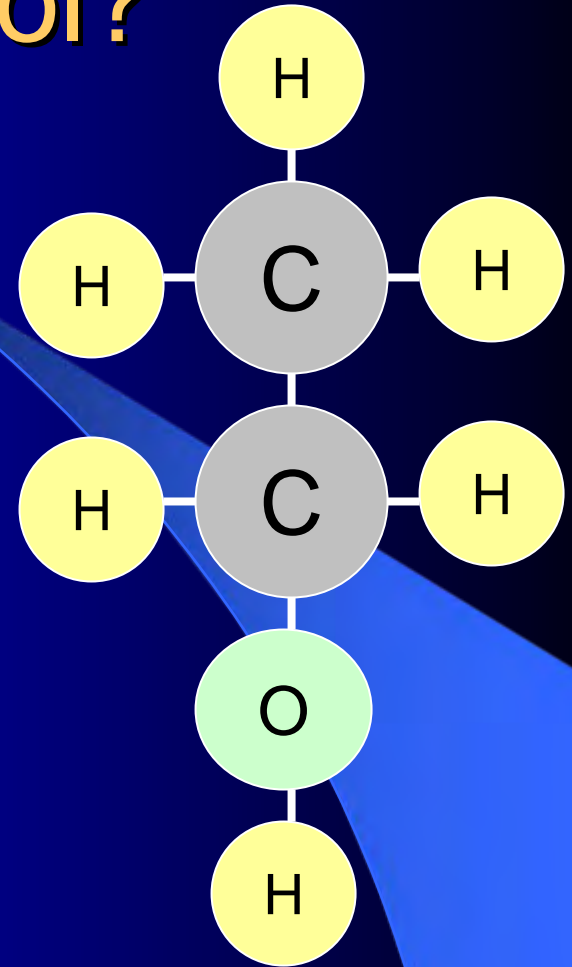
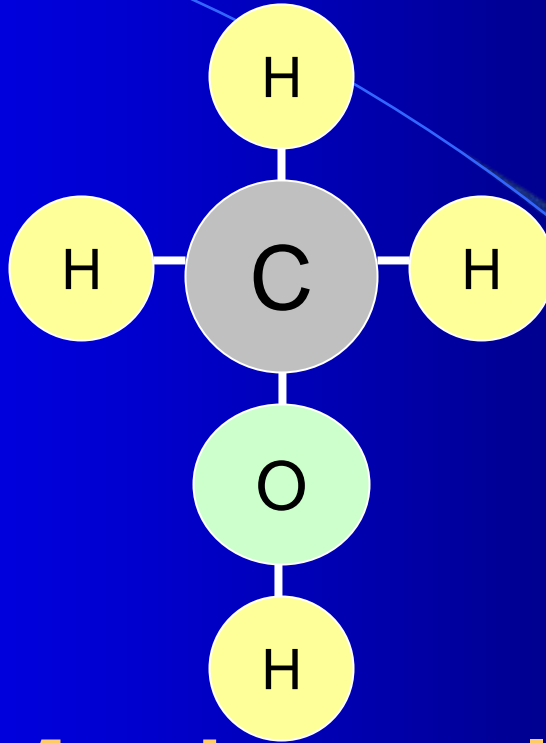
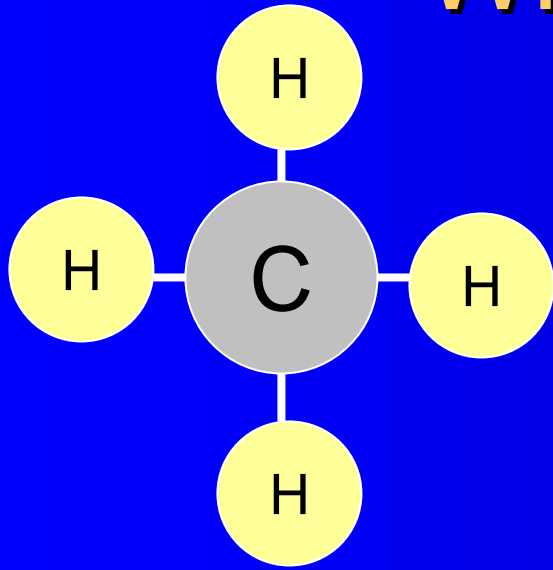


•Source: Cavallo of DOE, DHS in BAS etc

- 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!

What IS Methanol?



Methane

Natural Gas
Scarce as Oil
Needs Special
Tank

Methanol

Good H Carrier
Can Be Bioliquid
Or From Coal, Gas
Doubles bio-output?

Ethanol

e.g From Corn
Drinkable

GEM Flexibly Fuel Vehicles (FFV)

One Tank To Hold Them All

Full Retooling Doable in 2 years

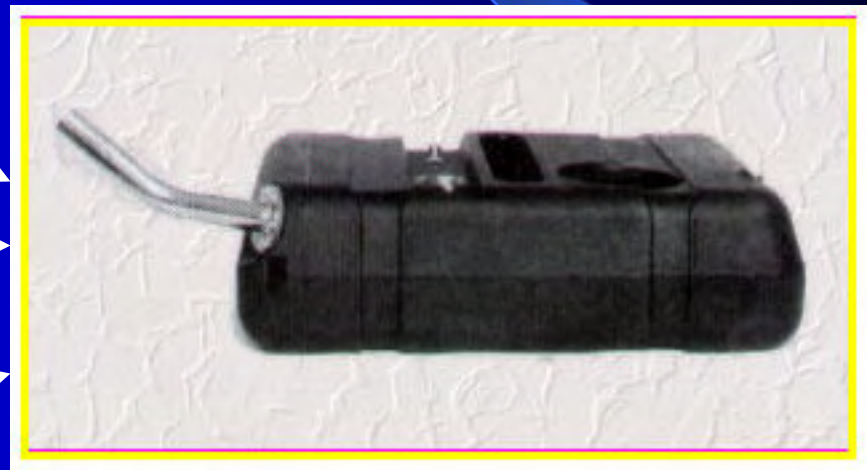
G: Gasoline



E: Ethanol



M: Methanol



With an FFV, you choose each day which fuel to buy.
At \$100-200/car, a more open competition, level playing field,
better unleash the power of the free market. Ford sold
Ks of GEM at no extra cost in Cal in '80s til gas went down.
>50% of new cars in Brazil GE flexible already.

GEM Flexibility Is Well-Established

ALCOHOL FUELS

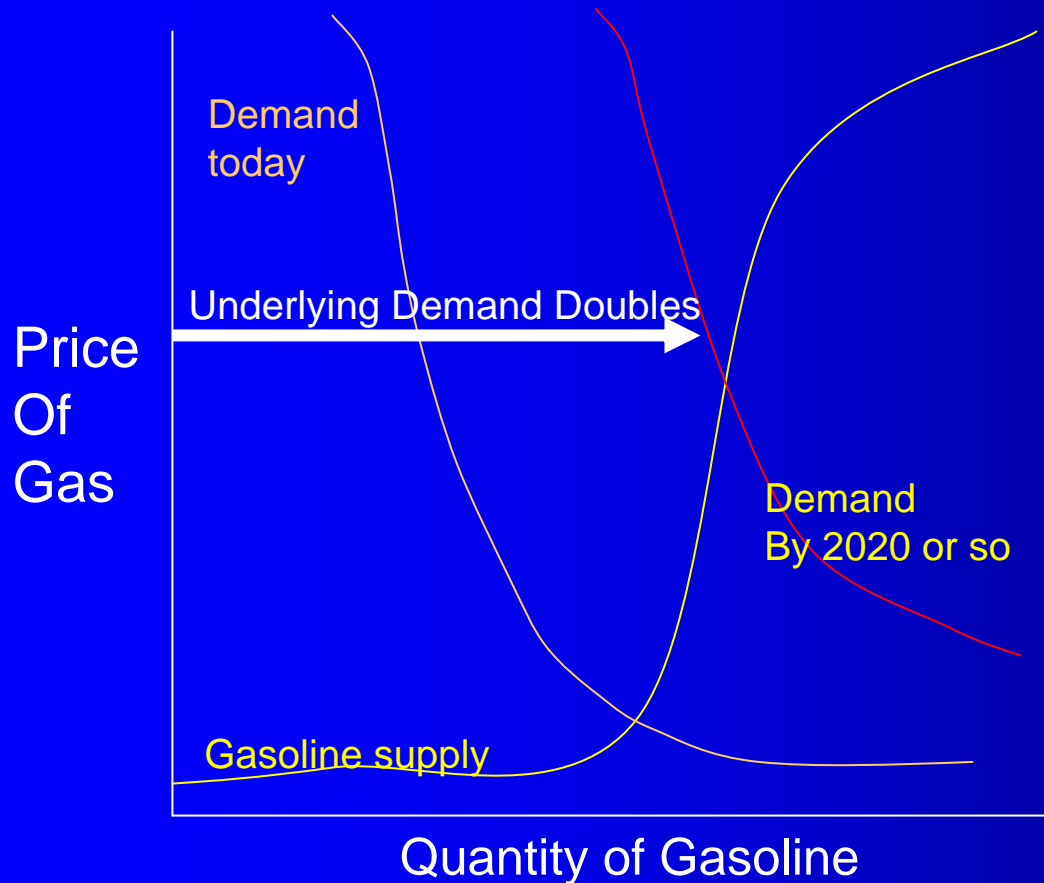
"Detroit is ready now to -- make cars that would run on any combination of gasoline and alcohol -- either ethanol, made from corn or methanol, made from natural gas or coal or even wood. Cars produce less pollution on alcohol fuels, and they perform better, too. Let us turn away from our dependence on imported oil to domestic products -- corn, natural gas, and coal -- and look for energy not just from the Middle East but from the Middle West."

Source: George Bush 1988 Campaign Brochures
www.4president.org

Rough but Unbiased Guess at What US Pays 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!!!**

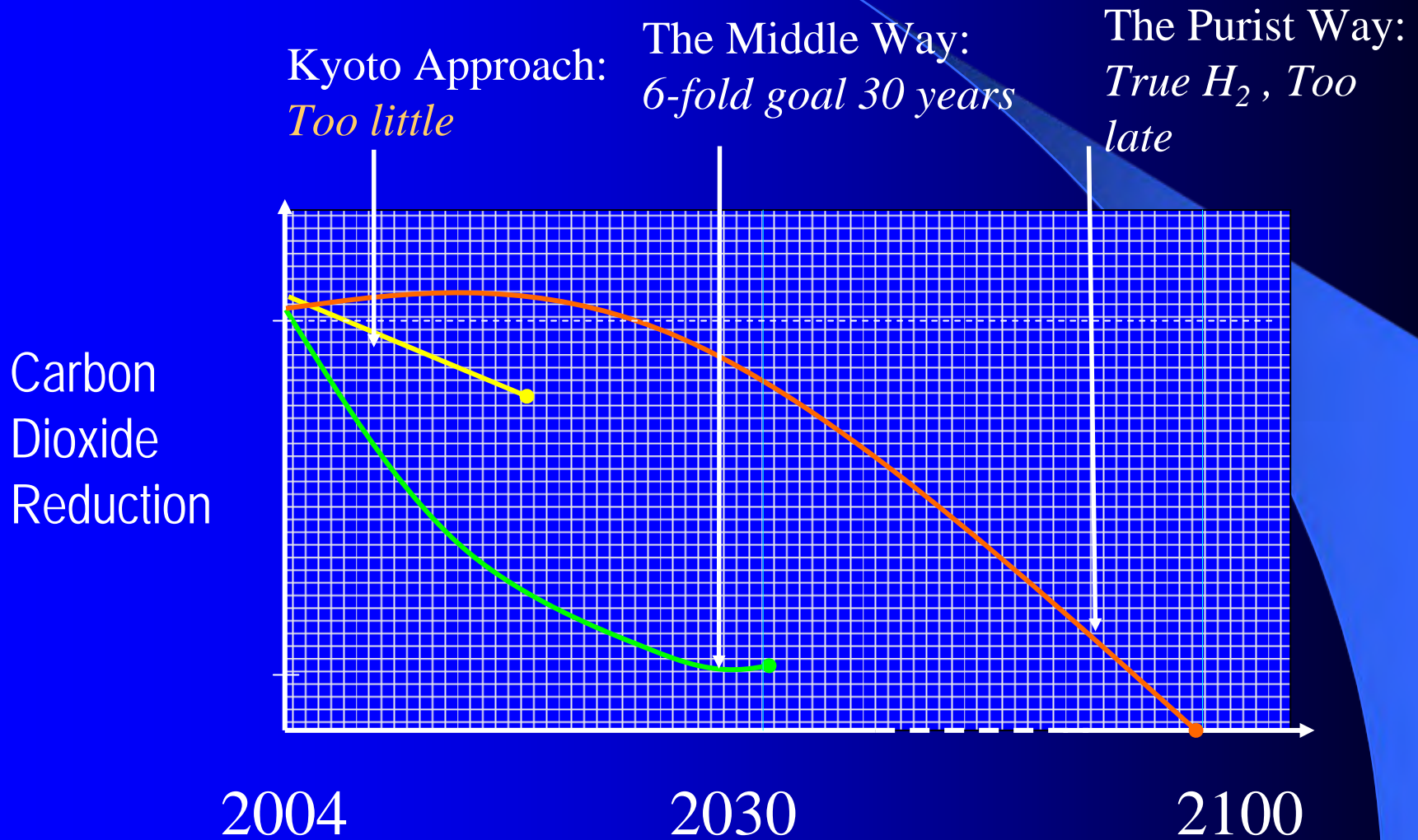
How will you cut your gasoline use by 50% or more?



- 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 = -0.2 ; price doubling Of GASOLINE only gives 14% reduction

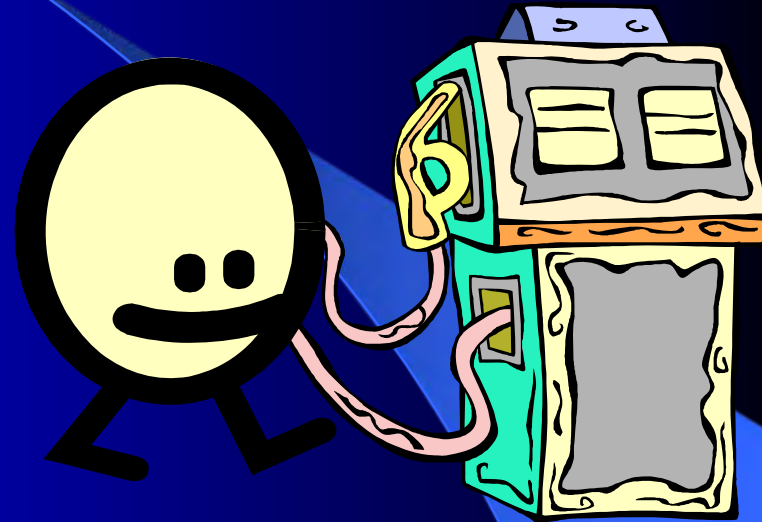
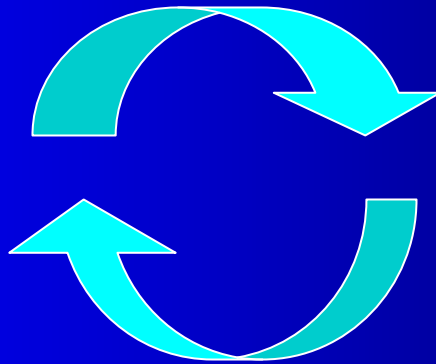
General Strategy: CO₂ As Example of Hard Work But No Solution



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?

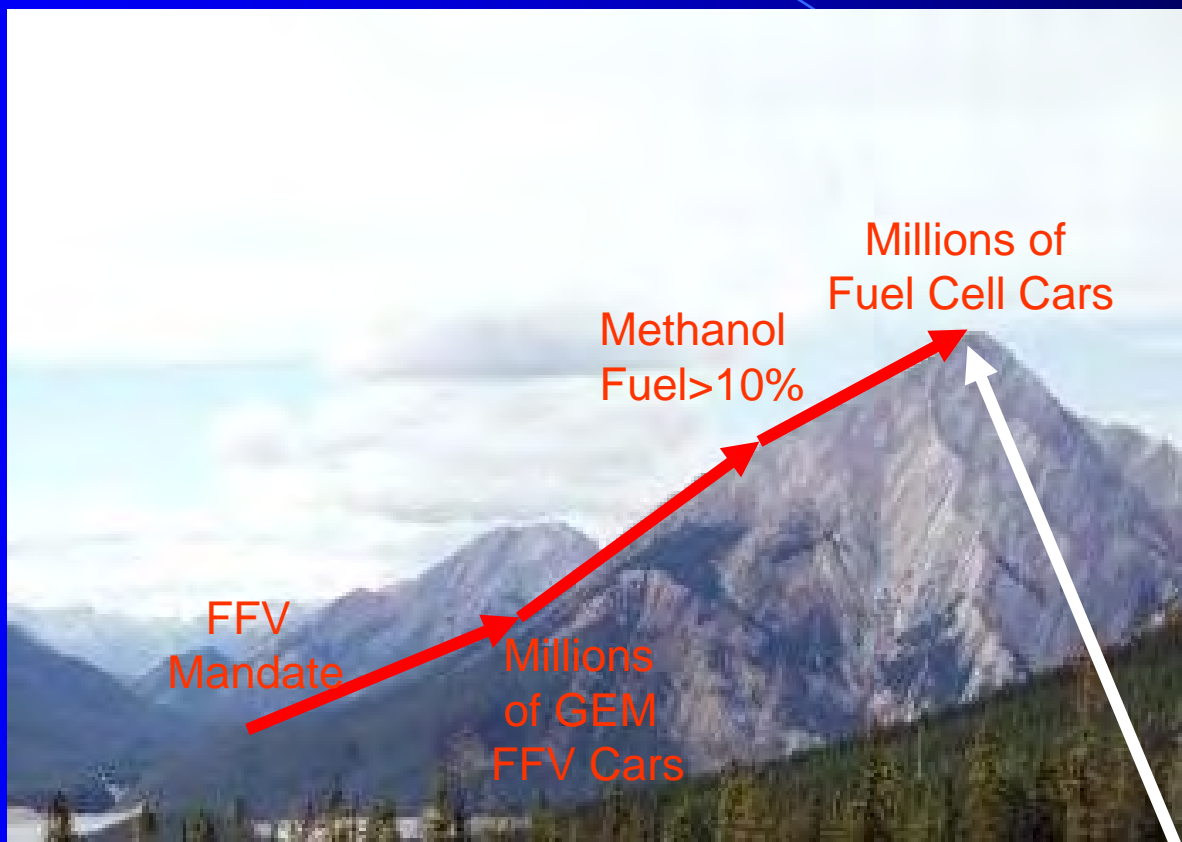


- Would **you** buy a car that only runs on H₂ **before** your local gas station carries H₂? Are PR stations enough?
- Would you invest \$trillion in gas stations and pipelines **before** people have H₂ cars?
- Technically: nonconvexity problem; **also high costs**

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?



Straight Up the Hydrogen Cliff?

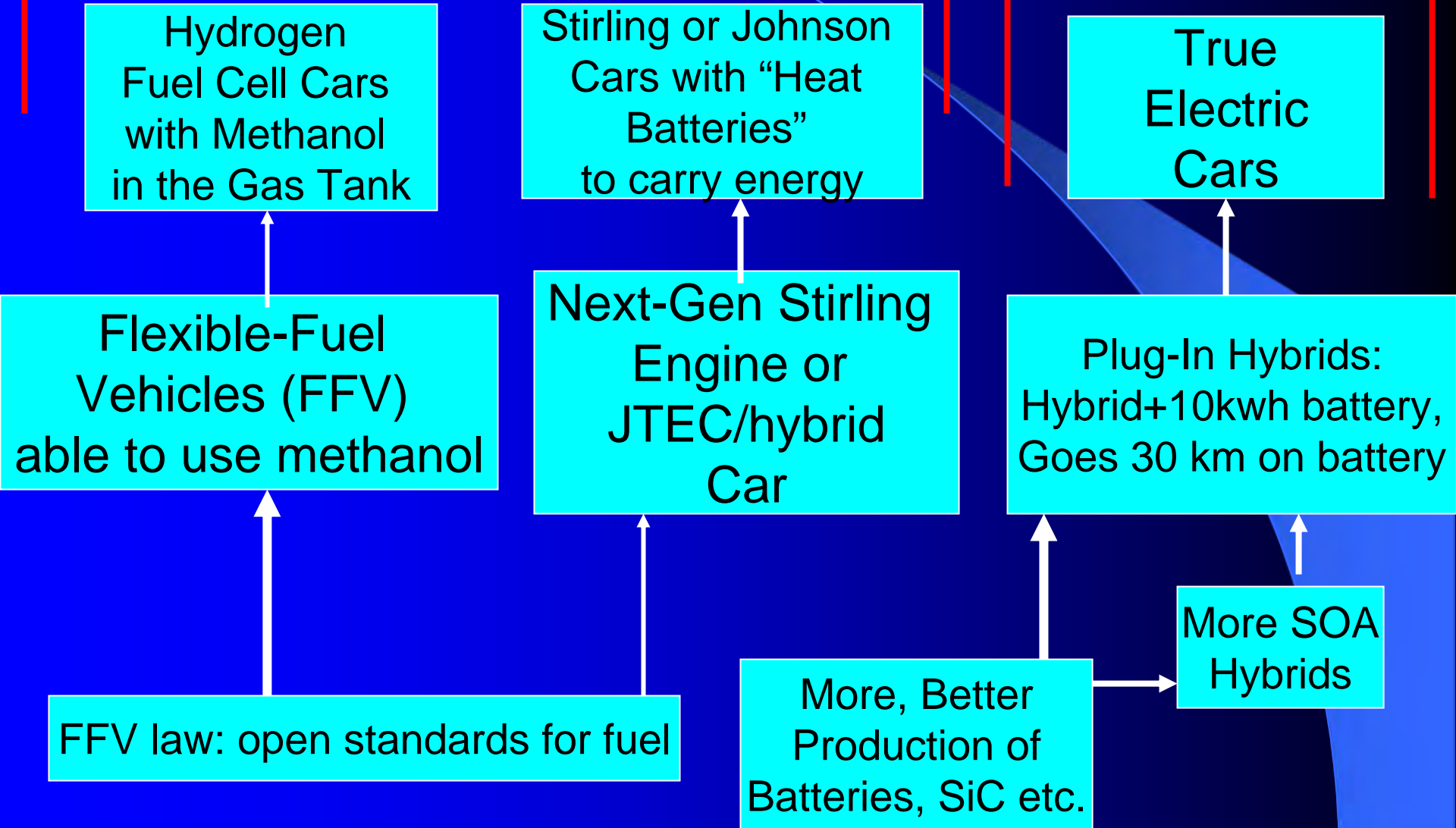
AREAS FOR NEEDED LEGAL REFORMS

- Ethanol+Methanol Fuel flexibility (up to M85) should be **MANDATORY** in new gasoline-using cars from 2006/7/8. Hybrids or advanced Stirling can also use GEM fuel tanks easily.
- Plug-in with >30km range should be **mandatory** in new hybrids, and incentivized for national security reasons
- Incentives and research opportunities for bio-methanol should be the same as for bioethanol, biohydrogen or better
- Zoning rules discouraging Distributed Generation should be modified to simplify renewable or alcohol fuel use
- Grid regulation needs to be made to fit "intelligence"
- Leak proof tanks in gas stations for ALL fuels. Tanks/pumps selling nonbiological M85 should be able to supply pure enough methanol for fuel cell cars.

3 Paths to Energy Independent Cars

Areas of US advantage, unused..

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



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

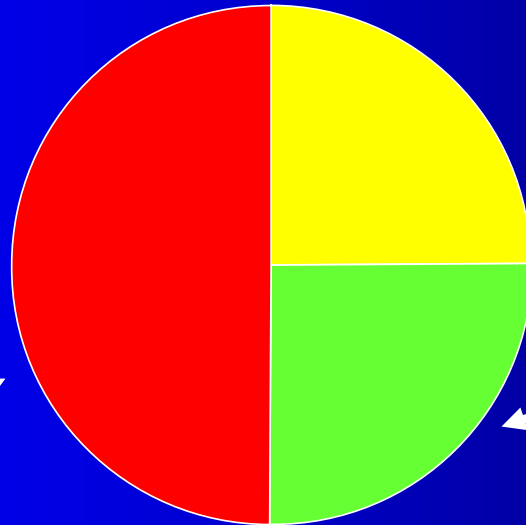
- FFV hybrids cut liquid fuel use 50% already. Plug-ins cut **50% of that**.
 - “Researchers have shown that (batteries) offering.. electric range of 32 km will yield... 50% reduction..” (IEEE Spectrum, July/05). Shown in working Prius.
- Battery **breakthroughs in China**: from 10/07, 10kwh batteries (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!



If we support unique key creative geniuses, we have chance of much better. For example, Lonnie G. Johnson

- Founder and President, Johnson R&D
- NASA (Voyager, Mars Observer, CRAF, Cassini, Galileo)
- Holds over 90 patents
- B.S. in Mechanical Eng., Tuskegee U.
- 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

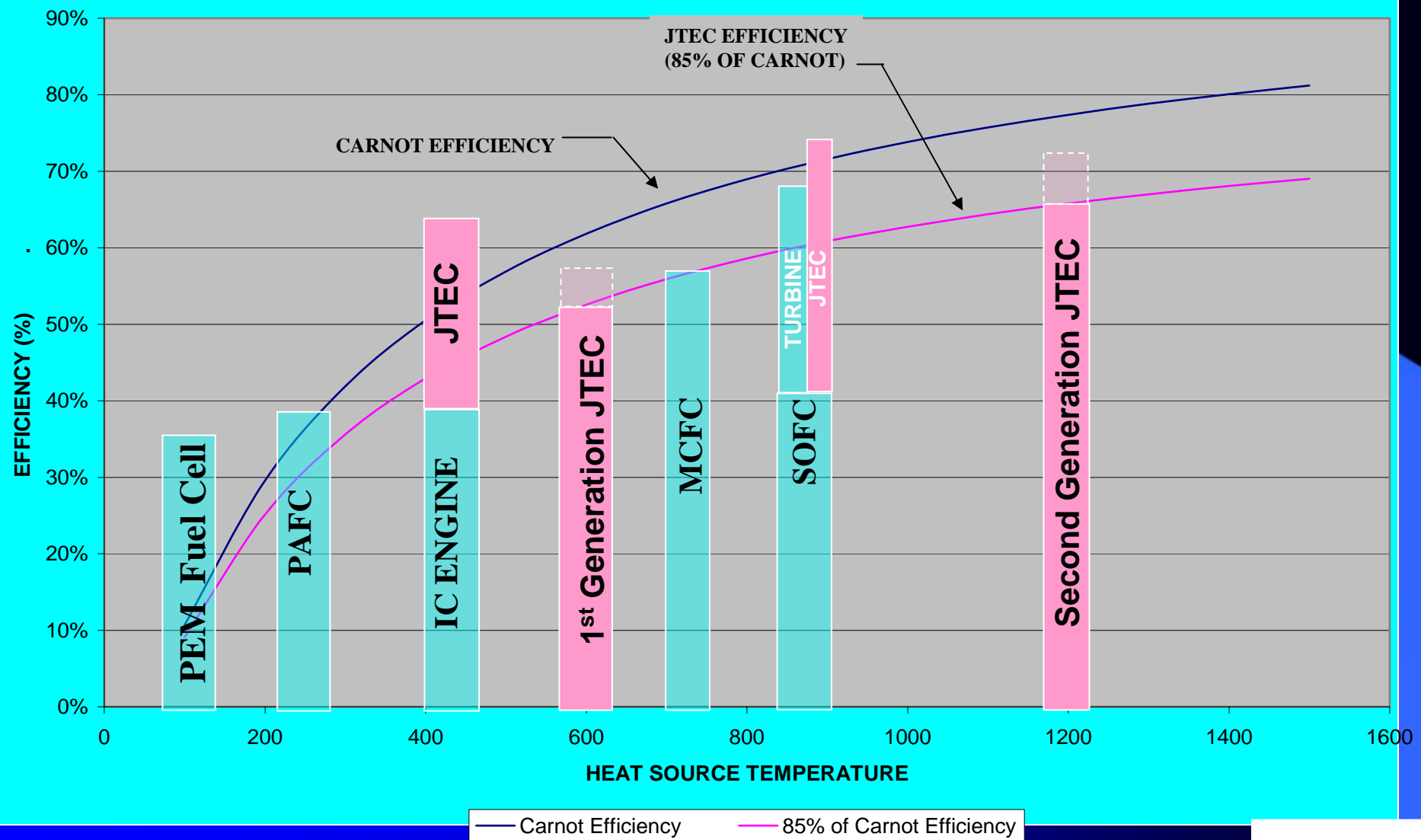
Exciting credible new ideas (risky but near term) for US to leapfrog the world both in batteries and in more efficient heat-to-electricity for flexible cars !!!!!!!

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

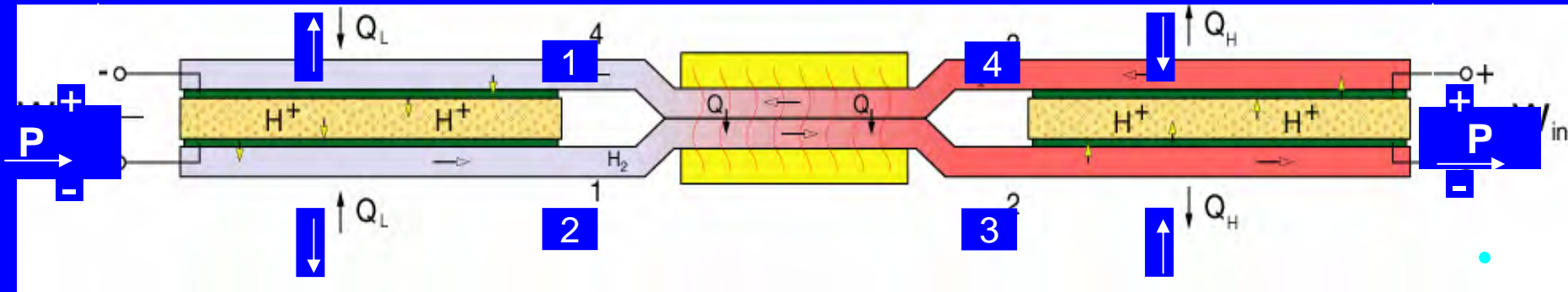
Chart Includes JTEC Operating on Waste Heat from Other Systems

EFFICIENCY OF FUEL CELL/ENGINE SYSTEMS

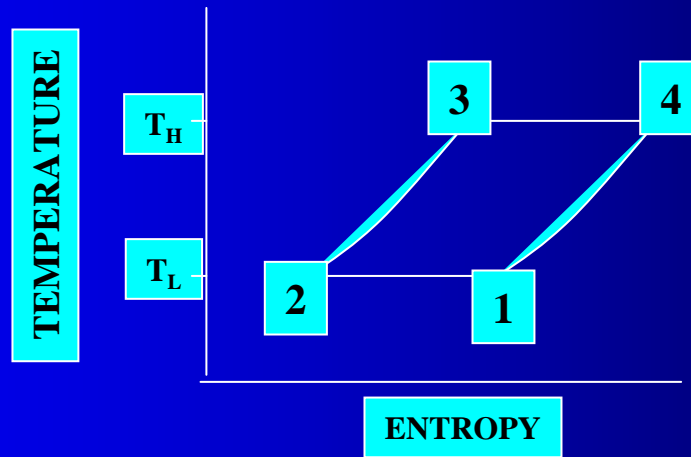
HEAT SINK TEMPERATURE = 60°C



JOHNSON THERMO-ELECTROCHEMICAL CONVERTER (JTEC) (patented)

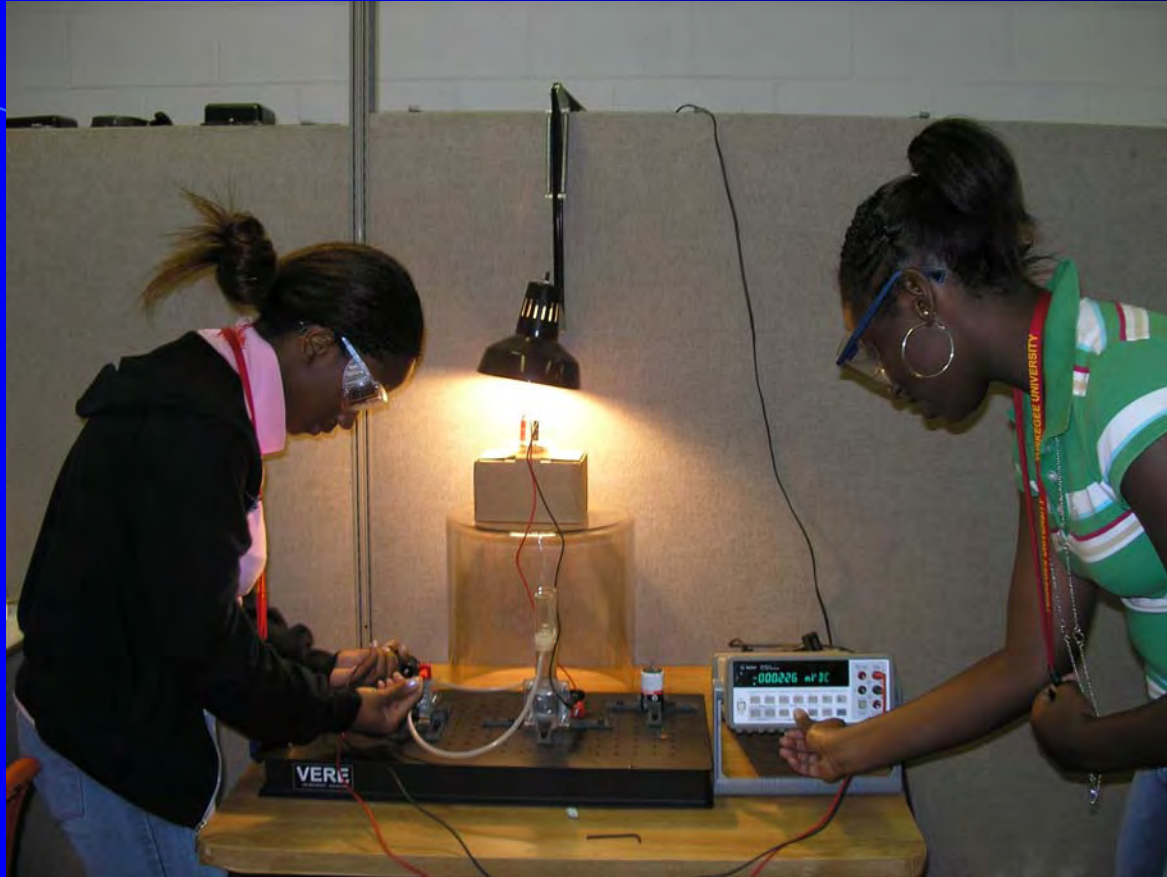


TEMPERATURE ENTROPY DIAGRAM FOR ERICSSON CYCLE



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!



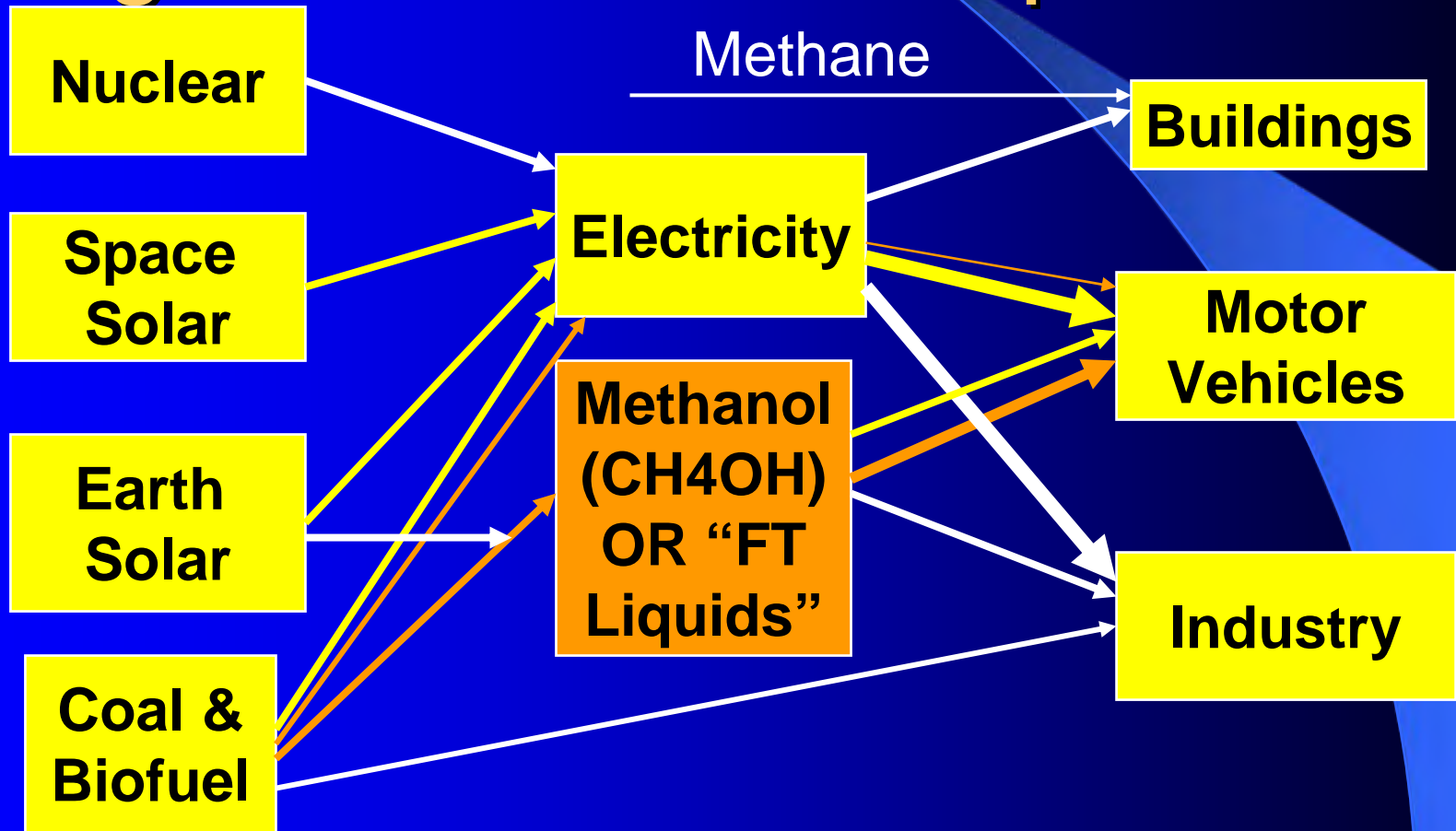
Excellent preliminary results from NSF SGER funding but more needed to bring to fruition.

•Batteries Too: Three New Concepts to Use Those Membranes to Outperform Today's Best 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

Johnson now makes/sells a rechargeable battery with high energy density, but needs support to scale up manufacturing to reduce unit cost – one of his three concepts

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!



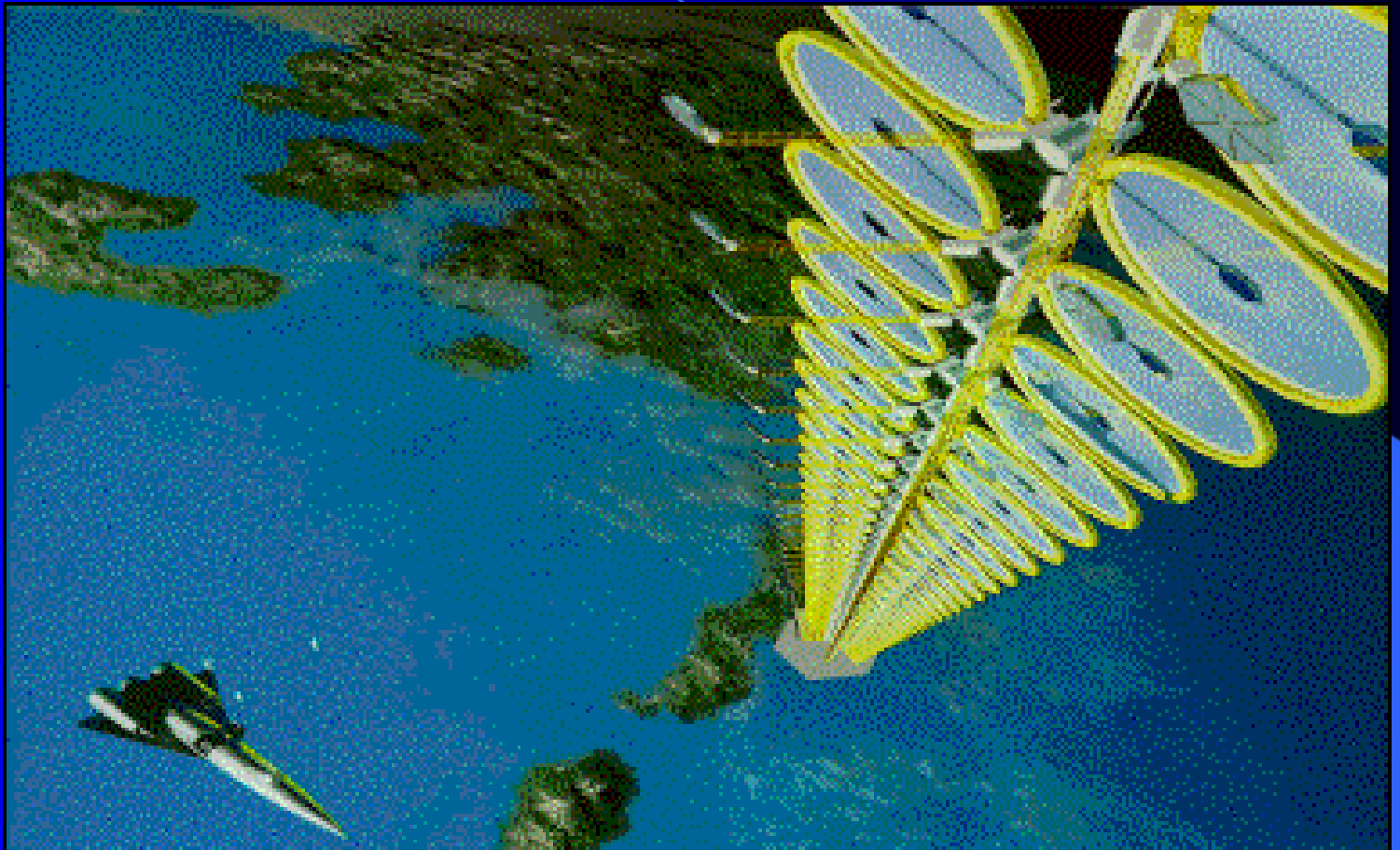
- Plug in JETC instead of Stirling to get more electricity from the same heat with the same type of new reflector! More electricity at same system cost would imply **even less than 4¢/kwh!**



- 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

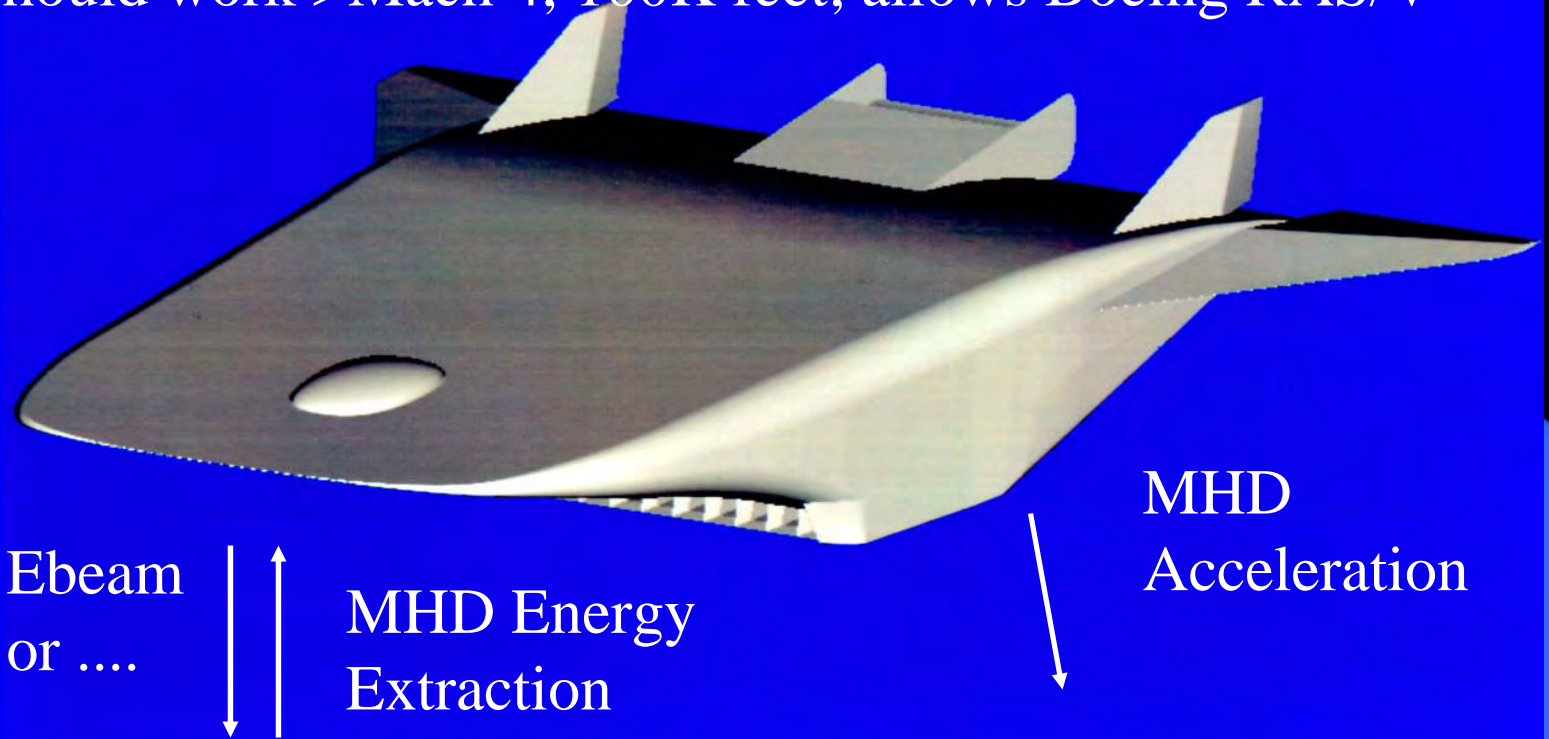
- Mankins' new version of solar cells to electricity to microwave
- Fork/Werbos (TIM 2002) “spinal cord” laser, light lenses/mirrors to **light-to-light laser** to earth
- Werbos **solar/fusion hybrid** lenses, laser, D-D pellets
- Nonterrestrial materials (**NTM**)
 - Idea not new; **Gerard O'Neill & 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

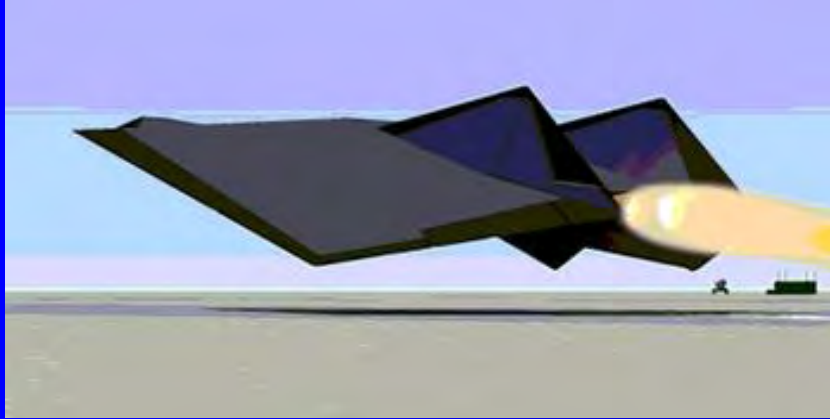
Plasma Hypersonics: ANSER/Chase NSF\$

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



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

3 PILLARS OF THE MIDDLE WAY

INDEPENDENT SUSTAINABLE CAR FUELS

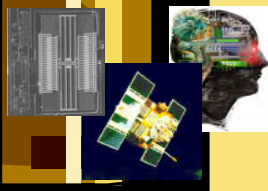


- Flexible fuel (e.g. Stirling)
- Plug-in hybrid – step to electric
- New type fuel cell cars
- Methanol production

TRULY INTELLIGENT POWER GRID



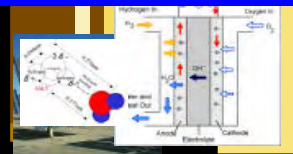
- Autonomous
- Adaptive
- Cyber Control
- MEMS, GPS



INDEPENDENT SUSTAINABLE ELECTRICITY



- Cleanest coal IGCC/sequest.
- “Solar farms”
- Space solar
- Also Team B?



Near-Term Big Technology Options That “Open the Door”, Get Us **Faster to 100% Sustainability**



(1): The Larger Space Strategy:
How Can We Maximize the
Probability That Human
Settlements in Space Will
SOMEDAY Achieve Self-
Sustaining Growth?

National Space Society

International Space Development Conference
2005, Arlington. Thanks to Gary Barnhard.

pwerbos@nsf.gov

Proposed Target (“Sustainability”)

- Revenue “to space” (“exports”) exceeds imports (from earth to space) – i.e. space earns more money than it costs
- Exports in space require inputs **large and diverse** enough to drive self-sustaining economic growth. (Economists would call this multiplier effects or takeoff or input-output capture.)
- Human skills and technologies advanced enough to respond effectively to the resulting markets in space (**NASA+NSF!**)
- **AS SOON AS POSSIBLE**, much bigger new revenue streams, such as the **three key synergistic options**:
 - **Space solar power**
 - Space tourism
 - Space manufacturing and materials
- Should all policy work back from the **target?**

For any hope to reach the stars, we need serious new physics beyond --

Quantum Field Theories (QFT)

QCD, The Quark Theory
Strong Nuclear Forces

EWT, Weak+QED

Quantum Electrodynamics QED

$$\mathcal{L} = -\frac{1}{4}(\partial_\lambda A_\nu - \partial_\nu A_\lambda)(\partial^\lambda A^\nu - \partial^\nu A^\lambda) + i\bar{\Psi}(\gamma \cdot \partial - ie\gamma \cdot A)\Psi - m\bar{\Psi}\Psi$$

Classical Field Theories

Einstein's
General
Relativity

- QFT is **not yet mathematically well-defined**, at least 4 versions
- **QED has been tested** in detail, electrical engineering, quantum optics, new math tools **essential to large-scale technology** – but measurement issues/hopes remain
- No empirical data yet to guide the unification of the three ellipses, **speculations...**
- QCD is widely assumed but mostly not tested..... E.g. see Makhankov..

QFT: Four Views of Schrodinger's Cat

1. The claws: the canonical version resting on creation/annihilation operators (claws), the first version.

Schrodinger
Picture:
Right claws

Heisenberg
Picture:
Left claws

(A cat is not a spider. The legendary third picture, the Interaction Picture, is said not to really exist.)



4. Spinning head or all-seeing eye:
Streater & Wightman,
"PCT, Spin, Statistics
and All That"

2. The quivering tail or Path: the "Feynman path Integral" (functional integral) version

3. The back used to roll over –
Wick transforms used to roll over (rotate)
From a Euclidean random lattice to Minkowski space

Options/Hopes For The Kinds of Breakthroughs That Could Matter...

- **QED**: No change in \mathcal{L} expected, but quantum measurement remains mysterious and may allow more power than now expected in quantum information technology. Unmet opportunities to follow up Yanhua Shih and Kim of Korea. Math tools already far stronger for technology purposes than in the rest of physics, but there is room to improve further; breakthroughs in lasers, energy scavenging, etc., seem likely – but no “warp drive.” New nanochip from Trew and Kim (NCSU) may open door to breakthroughs in quantum computing (time) and energy.
- Superstring and quantum loop speculate about exotic forces, but **no empirical data**. They still struggle to match “QCD,” assumed to be perfect. Superstrings like epicycles, protected by the College of Cardinals? Loops, its-from-bits maybe later.
- But: **strong nuclear forces are not well known empirically**. QCD not fully tested. Schwinger proposed alternative theory more compatible with easy grand unification and reality. Sawada says **decisive empirical test has been done – and favors Schwinger!** See www.werbos.com/reality.htm for how to formulate the Schwinger model in a way that allows use of the mathematical tools used in QED (generalized to the nuclear case), which also provide mathematical well-definedness, reality & a natural path to unification with gravity (“bending space”). But be careful – important, necessary, but also very dangerous!! See www.werbos.com/space.htm.
- Some details of EWT are also untested, affect larger-scale time directions, and may be important on the cosmological scale where small feedback terms may accumulate.