

ENERGY, POLITICS AND SPACE

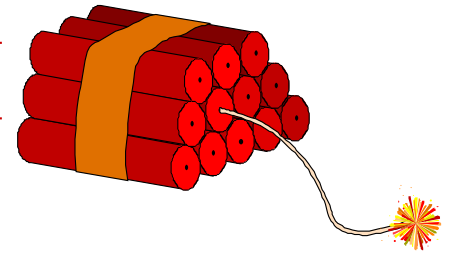
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TOFE

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Madison, Wisconsin

THE PROBLEM



- **10 -12 BILLION EARTHLINGS BY 2050**
- **>X8 INCREASE IN ENERGY DEMAND**
 - **X2 TO STAY EVEN WITH 2000 DEMAND**
 - **X4 OR MORE TO MEET ASPIRATIONS AND SLOW POPULATION GROWTH (NOTE CHINA!)**
 - **X? TO MITIGATE CLIMATE CHANGE**
- **HOW IS FUTURE DEMAND TO BE MET?**
 - **ASSUME PRIVATE FINANCING OF NEW CAPACITY IS REQUIRED**

IN THE BOX SOLUTIONS



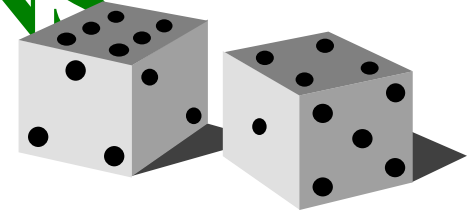
- **CONSERVATION / EFFICIENCY**
 - **$\Delta \text{ COST} = \text{ENERGY PRICE} \times \text{INCREASE IN USAGE}$**
 - **CONSERVATION ETHIC**
 - **RESEARCH AND TECHNOLOGY DEVELOPMENT**
 - **REGULATION ?**
 - **MILEAGE / EFFLUENT**
 - **CONVERSION EFFICIENCY**
 - **RENEWABLES MANDATES**
- **IMPORTANT BUT NOT ENOUGH**

IN THE BOX SOLUTIONS

- **FOSSIL FUELS** (OIL, NAT. GAS, COAL, TAR, METHANE)
 - ACE IN THE HOLE #1 (INCLUDES H₂)
 - RESERVES UNCERTAINTY
 - X2+ INCREASE OF UNKNOWN IMPACT
 - FUTURE VALUE AS FEED STOCK
 - SUPPLY & PRICE VULNERABILITY / CONFLICT
 - ENVIRONMENTAL RESTRICTIONS
 - ON PRODUCTION
 - ON USE (CLIMATE CHANGE AND HEALTH)
- **NOT PRUDENT TO DEPEND ON THIS FOR MORE THAN A FEW DECADES**



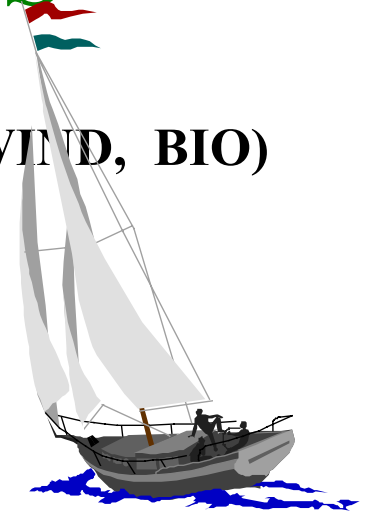
IN THE BOX SOLUTIONS



- **NUCLEAR FISSION**
 - ACE IN THE HOLE #2
 - EXTREMELY LOW GREENHOUSE EMISSIONS POST-CONSTRUCTION
 - HEALTH AND SAFETY RISK LOW
 - POLITICALLY DIFFICULT
 - ELECTION ISSUE
 - WASTE DISPOSAL
 - GOVERNMENT FAILURE TO PROVIDE
 - ELECTION ISSUE
 - WEAPONS PROLIFERATION
 - ELECTION ISSUE
 - REACTORS ARE TERRORISM TARGETS
 - ADDED COST
 - TERRORIST STATES' REACTORS INVITE PREEMPTION
- **NOT YET A GLOBAL SOLUTION POLITICALLY**

IN THE BOX SOLUTIONS

- **TERRESTRIAL SOLAR (PHOTO, THERMAL, WIND, BIO)**
 - **REGIONAL ACE IN THE HOLE**
 - **FEED TO BASE LOAD GRID**
 - **OTHERWISE NEEDS ENERGY STORAGE**
 - **LAND USE / BIRD STRIKE / ETC. ISSUES**
 - **FULLY BURDENED COST ISSUES**
 - **NET ENVIRONMENTAL IMPACT**
 - **PROBABLY UNCERTAIN AT THIS TIME**
 - **EXCEPT FOR SPECIAL GEOGRAPHIC CIRCUMSTANCES**
 - **BIO-SOLAR HYDROGEN GENERATION?**
- **NOT A FEASIBLE GLOBAL SOLUTION**



CONCLUSION

**NO NEAR-TERM, AGREED TO
SOURCE FOR AN >8X
INCREASE IN ENERGY
DEMAND BY 2050**

COMBINATION OF:

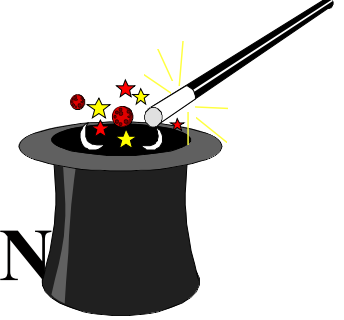
POLITICS

SUPPLY

TERRORISM

ENVIRONMENTAL AGENDAS

OUT OF THE BOX SOLUTIONS



- **D/T MAGNETIC AND INERTIAL FUSION**
 - MAJOR INTERNATIONAL MCF R&D EFFORT
 - STALLED POLITICALLY AT PRESENT TIME
 - LARGE PLANT SIZE
 - PROTOTYPE DEMONSTRATION REQUIRED
 - **MATERIALS ENGINEERING UNKNOWNNS EXIST**
 - **WASTE DISPOSAL**
 - RADIOACTIVE, COSTLY FUEL CYCLE
 - ANTI-NUCLEAR ACTIVIST'S OPPOSITION
 - CONSTRUCTION COSTS HIGH BUT UNKNOWN
 - PATH TO CAPITAL MARKETS NOT APPARENT
 - NEEDS "APPLES TO APPLES" COMPARISONS WITH COMPETITORS

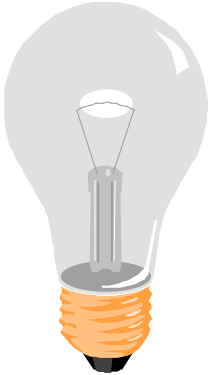
OUT OF THE BOX SOLUTIONS



- **SPACE SOLAR**

- **LARGE SPACE CONSTRUCTION PROJECTS DEMONSTRATED BY ISS**
- **CONCEPT WELL-STUDIED (EXCEPT FINANCIAL)**
- **PROTOTYPE DEMONSTRATION REQUIRED**
- **LAUNCH COST REDUCTION REQUIRED**
- **SPACE LAW ENVIRONMENT**
 - **PROBABLY PERMISSIVE / NEEDS FEDERAL ADVOCACY**
- **POWER BEAMING POLITICAL ISSUES**
- **PATH TO CAPITAL MARKETS NOT APPARENT**
- **NEEDS “APPLES TO APPLES” COMPARISON WITH COMPETITORS**
- **NEEDS SUPPORTIVE FEDERAL ATTITUDE**

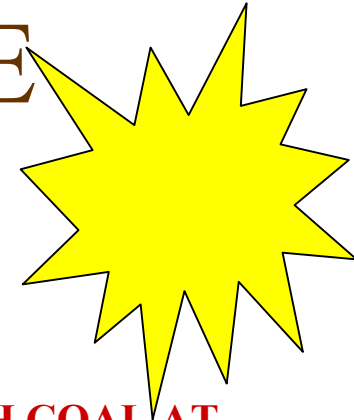
OUT OF THE BOX SOLUTIONS



- **LUNAR HELIUM-3 FUSION**
 - **NUCLEAR POWER WITHOUT NUCLEAR WASTE**
 - **<\$15 BILLION IN R&D TO BE FINANCIALLY VIABLE**
 - **PROTOTYPE DEMONSTRATION REQUIRED**
 - **FACTOR OF ~20 REDUCTION IN APOLLO LAUNCH COSTS**
 - **DEVELOPMENT OF LUNAR PRODUCTION SYSTEM**
 - **PERMANENT LUNAR SETTLEMENT**
 - **SPACE LAW ENVIRONMENT**
 - **PERMISSIVE / NEEDS FEDERAL ADVOCACY**
 - **PATH TO CAPITAL MARKETS**
 - **NEAR-TERM APPLICATIONS FOR $Q \ll 1$ AND < 1 FUSION**
 - **NEEDS “APPLES TO APPLES” COMPARISON WITH COMPETITORS**
 - **NEEDS SUPPORTIVE FEDERAL ATTITUDE**

LUNAR HELIUM-3 EXAMPLE

~4 BILLION
YEARS



- >10,000 TONNES IN UPPER 3M OF MARE TRANQUILLITATIS
- <100KG REQUIRED FOR 1GW PLANT
- LUNAR POLES AND PROCELLARUM MAY PROVIDE ADDITIONAL EARLY POTENTIAL RESOURCE
 - VERIFICATION REQUIRED
- MINING, PROCESSING, AND REFINING CONCEPTUALLY STRAIGHT FORWARD
 - MAXIMIZE AUTOMATION
- NEED LAUNCH COSTS <\$3000/KG
 - LONG-TERM PRODUCTION
 - MODERN TECHNOLOGY
 - PROVEN CONCEPTS
 - (BEEN THERE, DONE THAT!)
- COULD COMPETE WITH COAL AT \$2.50/MBTU (CURRENTLY ~\$2.10)
- BREAKEVEN FOR PRODUCTION AND POWER AT ~5, 1GW PLANTS
 - ADDITIONAL VALUE IN BY-PRODUCTS FOR USE IN SPACE
- ~15 BILLION R&D COSTS
- HE-3 FUSION TECHNOLOGY
 - PROMISES LOW CAPITAL COSTS
 - NO RADIOACTIVE WASTE
 - HIGH CONVERSION EFFICIENCY
 - NEAR-TERM APPLICATIONS
 - PATH TO CAPITAL MARKETS

CONCLUSION

**SEVERAL LONG-TERM TECHNICAL
SOURCES FOR AN >8X INCREASE IN
ENERGY DEMAND BY 2050**

REQUIRES:

**INTELLIGENT FEDERAL EFFORTS
PRIVATE SECTOR ENTREPRENEURS AND
INVESTORS
COMPETENT AND DISCIPLINED
MANAGEMENT**

“OUT OF THE BOX” DEVELOPMENT PROGRAMS

- APOLLO WAS CERTAINLY “OUT OF THE BOX” FOR ITS TIME**
- ARE THERE LESSONS TO BE LEARNED FROM APOLLO RELATIVE TO NEW ENERGY SYSTEMS?**

APOLLO MANAGEMENT

BROAD APPROACH

- **SET ATTAINABLE OBJECTIVE**
 - **COMPONENTS OF SUCCESS OR FAILURE CLEAR**
- **ESTABLISH ADMINISTRATIVE APPROACH**
 - **COMBINE HARDWARE AND PROGRAMS**
 - **FLEXIBLE IMPLEMENTATION AT SPECIALIZED CENTERS**
 - **CENTERS REPORT TO PROGRAM OFFICES**
 - **SENIOR MANAGEMENT WORKS EXTERNAL ISSUES**
 - **PROVIDES TECHNICALLY COMPETENT OVERSIGHT**
 - **CONTRACT OUT MOST R&D**
 - **PARALLEL INTERNAL DESIGN / ENGINEERING**
 - **RIGOROUS COMPONENT TESTING / “ALL-UP” FLIGHT TESTING**
 - **SUFFICIENT MANAGEMENT RESERVE**

APOLLO'S KEYS TO SUCCESS

- **SUFFICIENT BASE OF TECHNOLOGY**
 - **WWII / COLD WAR / EISENHOWER DECISIONS**
- **RESERVOIR OF YOUNG ENGINEERS AND SKILLED WORKERS**
 - **1957 “SPUTNIK” GENERATION**
- **PERVASIVE ENVIRONMENT OF NATIONAL UNEASE**
 - **CAMPAIGN OF 1960**
- **CATALYTIC EVENT THAT BRINGS FOCUS**
 - **GARGARIN’S FLIGHT**
- **TRUSTED AND PERSUASIVE PRESIDENT**
 - **JOHN F. KENNEDY**
- **COMPETENT AND DISCIPLINED MANAGEMENT**
 - **POST-APOLLO 204 FIRE**



ENERGY'S KEYS TO SUCCESS

- SUFFICIENT BASE OF TECHNOLOGY
 - EXISTING BASE ENHANCEMENT ALONG MULTIPLE PATHS
- RESERVOIR OF YOUNG ENGINEERS AND WORKERS
 - FUND UNIVERSITY-BASED RESEARCH
 - IMPROVE ELEMENTARY AND SECONDARY SCHOOLS
- PERVASIVE ENVIRONMENT OF NATIONAL UNEASE
 - CURRENT CLIMATE OF UNEASE SHOULD SUFFICE
- CATALYTIC EVENT THAT BRINGS FOCUS
 - 9/11
- TRUSTED AND PERSUASIVE PRESIDENT
 - TIME WILL TELL
- COMPETENT AND DISCIPLINED MANAGEMENT
 - ?????????????????????????????????

