ENERGY, POLITICS AND SPACE

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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 EMMISIONS 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

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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 UNKNOWNS 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<<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

SOLAR WIND

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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

• PERVERSIVE ENVIRONMENT OF NATIONAL UNEASE
  – CAMPAIGN OF 1960

• CATALYTIC EVENT THAT BRINGS FOCUS
  – GAGARIN’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
• PERVERSIVE 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
  – ????????????????????????