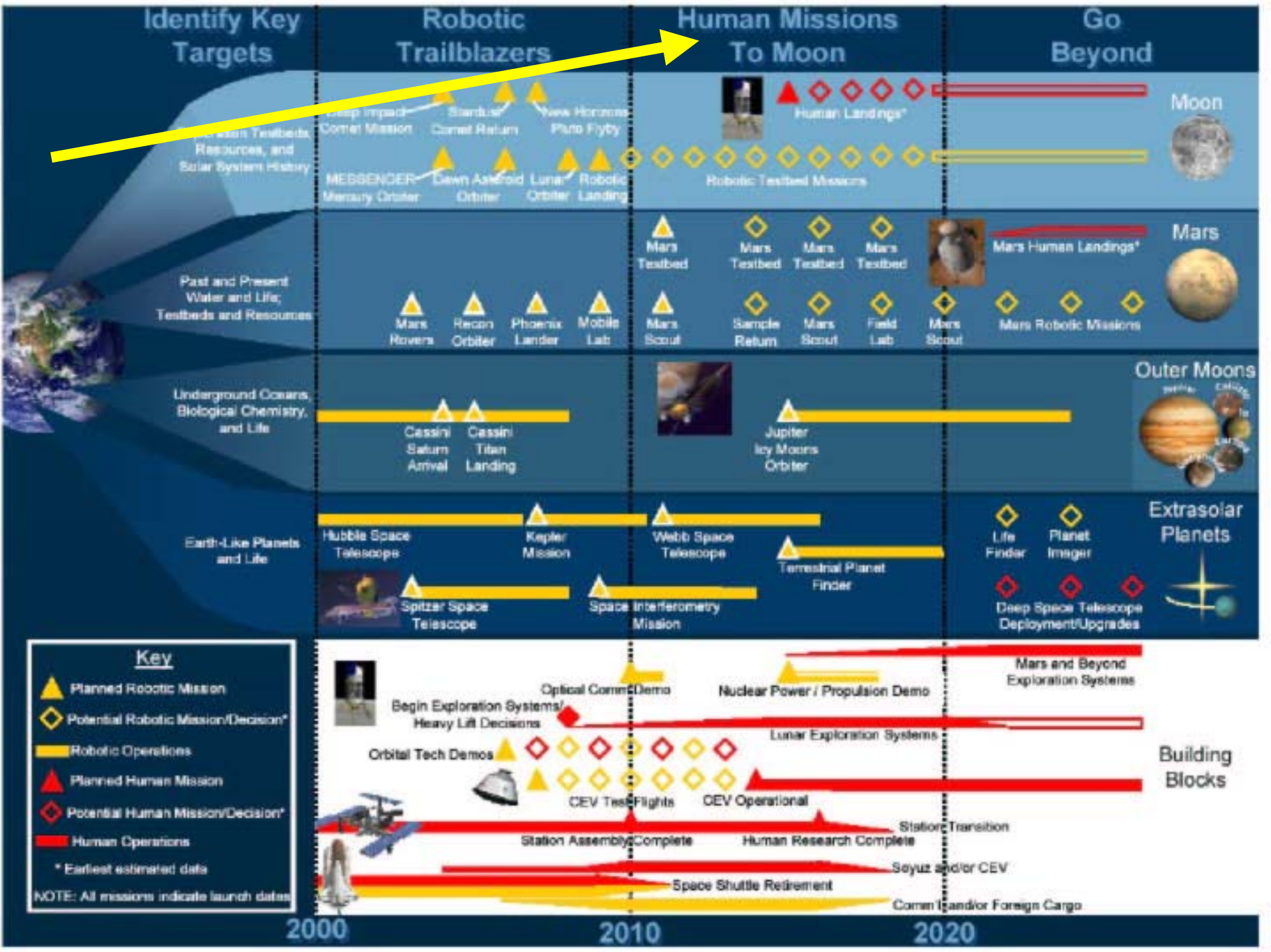
LUNAR / MARS ACTIVATION - 1
NEEP 533 LECTURE 30

Harrison H. Schmitt


Identify Key Targets
Robotic Trailblazers
Human Missions To Moon
Go Beyond
Solar System Testbeds, Resources, and Solar System History
Deep Impact Comet Mission
Stardust Comet Return
New Horizons Pluto Flyby
MESSENGER Mercury Orbiter
Dawn Asteroid Orbiter
Lunar Orbiter
Robotic Landing
Human Landings*
Robotic Testbed Missions
Moon
Past and Present Water and Life; Testbeds and Resources
Mars Rovers
Recon Orbiter
Phoenix Lander
Mobile Lab
Mars Testbed
Mars Scout
Sample Return
Mars Testbed
Mars Testbed
Mars Testbed
Mars Scout
Field Lab
Mars Scout
Mars Human Landings*
Mars Robotic Missions
Mars
Underground Oceans, Biological Chemistry, and Life
Cassini Saturn Arrival
Cassini Titan Landing
Jupiter Icy Moons Orbiter
Outer Moons
Earth-Like Planets and Life
Hubble Space Telescope
Kepler Mission
Webb Space Telescope
Terrestrial Planet Finder
Spitzer Space Telescope
Space Interferometry Mission
Life Finder
Planet Imager
Deep Space Telescope Deployment/Upgrades
Extrasolar Planets
Key
Planned Robotic Mission
Potential Robotic Mission/Decision*
Robotic Operations
Planned Human Mission
Potential Human Mission/Decision*
Human Operations
* Earliest estimated date
NOTE: All missions indicate launch dates
Optical Comm Demo
Begin Exploration Systems/ Heavy Lift Decisions
Nuclear Power / Propulsion Demo
Mars and Beyond Exploration Systems
Lunar Exploration Systems
Orbital Tech Demos
CEV Test Flights
CEV Operational
Building Blocks
Station Assembly Complete
Human Research Complete
Station Transition
Soyuz and/or CEV
Space Shuttle Retirement
Comm and/or Foreign Cargo
2000
2010
2020

Key Elements of the Nation's Vision

- **Objectives**
  - Implement a sustained and affordable human and robotic program
  - Extend human presence across the solar system and beyond
  - Develop supporting innovative technologies, knowledge, and infrastructures
  - Promote international and commercial participation in exploration

- **Major Milestones**
  - 2008: Initial flight test of CEV
  - 2008: Launch first lunar robotic orbiter
  - 2011 First Unmanned CEV flight
  - 2014: First crewed CEV flight
  - 2015: Jupiter Icy Moon Orbiter (JIMO)/Prometheus
  - 2015-2020: First human mission to the Moon

NASA APPROACH TO LUNAR "BASE" ACTIVATION

- **2004-2010: SPACE BIOMEDICAL RESEARCH AT ISS**
- **2010? : SPACE SHUTTLE RETIREMENT**
- **2004-2014: CEV "CONSTELLATION" & LUNAR ACCESS DEVELOPMENT**
- **2008-2020: ROBOTIC MISSIONS TO EXPAND ON CURRENT KNOWLEDGE**
- **2015-2020: DEMONSTRATE PERMANENT LUNAR INFRASTRUCTURE / PERMANENT HUMAN PRESENCE?**
- **2015-202?: DEMONSTRATE EXTRACTION OF LUNAR RESOURCES**
  - **SPACE CONSUMABLES ONLY**
- **202?-------: USE LUNAR RESOURCES FOR MORE COST-EFFECTIVE ACCESS TO SPACE**

DETAILS IN-WORK

NASA 2004 PLAN / MARBURGER, 2/12/04

NASA APPROACH TO MARS "BASE" ACTIVATION

- **2004-202?: USE ROBOTIC MISSIONS TO EXPAND ON CURRENT KNOWLEDGE**

- **2015-202?: DEMONSTRATE AVAILABILITY OF LUNAR RESOURCES**
  - **SPACE CONSUMABLES ONLY**
- **201?-202?: MARS ACCESS & EXPLORATION INFRASTRUCTURE DEVELOPMENT**
- **202?-------: USE LUNAR RESOURCES FOR MORE COST-EFFECTIVE ACCESS TO SPACE INCLUDING MARS**

- **202?-------: INITIATE HUMAN EXPLORATION**

DETAILS IN-WORK

NASA 2004 PLAN / MARBURGER, 2/12/04

OR, THE PRIVATE SECTOR MIGHT DO SOMETHING A LITTLE MORE FOCUSED

EQUIPMENT AND PEOPLE

HELIUM-3 FUSION FUEL

SETTLERS

FUSION POWER TECHNOLOGY

OPERATIONS MANAGEMENT

INVESTORS

BUSINESS MANAGEMENT

FIRST HUMAN MISSION TO THE MOON: 10-18 YEARS AFTER REACHING INITIAL INVESTMENT MILESTONE OF $15 M.

INITIAL "BUSINESS" APPROACH TO LUNAR BASE ACTIVATION

** APPLIES TO NASA OR PRIVATE INITIATIVE

- "BUSINESS" PLAN DEVELOPMENT
  - FINANCIAL COMMITMENTS**
  - COORDINATION WITH AND MARKETING TO RESOURCE USERS**
- DETAILED EVALUATION AND CHARACTERIZATION OF THE RESOURCE BASE
  - GRADE (CONCENTRATION)**
  - GEOTECHNICAL PARAMETERS**
- DEFINITION OF ENGINEERING DESIGN PARAMETERS FOR BASE AND MINING AND PROCESSING FACILITIES
  - MINE PLANNING**
  - DEVELOPMENT OF ARCHITECTURE AND ACTIVATION SEQUENCE**
  - LUNAR SURFACE EQUIPMENT REQUIREMENTS**
  - LAUNCH VEHICLE & SPACECRAFT REQUIREMENTS**
- FINAL DEFINITION OF LAUNCH AND SUPPORT ECONOMICS**
- COMMITMENT TO DETAIL DESIGN, MANUFACTURE, AND IMPLEMENTATION**

FOR PRIVATE INITIATIVE, PROGRESS LIMITED UNTIL COMMERCIAL HE-3 FUSION DEMONSTRATED

<$1000/KG TO THE MOON VS. $57,000/KG
~100 TONNES TO THE MOON VS. 48 TONNES
PARTIALLY RE-USABLE? VS. EXPENDABLE
COMPARABLE RELIABILITY (~100%)
LONG TERM PRODUCTION VS. FIXED NUMBER
NO LONG TERM STAND DOWNS VS. APOLLO 13 & SHUTTLE

NEW SATURN VS. SATURN V:

NOTE: NASA'S INITIAL PLAN IS TO USE COMBINATIONS OF AVAILABLE ELVs WITH EARTH-ORBIT ASSEMBLY

RISK, PRODUCTIVITY, AND COST MANAGEMENT -1: EQUIPMENT

**** SHOULD APPLY TO NASA OR PRIVATE INITIATIVE**

- **NO LONG TERM STAND-DOWNS IN LAUNCHES TO MOON**
  - **FIRM BOOSTER DESIGN CRITERION**
- **LUNAR EQUIPMENT DESIGN**
  - **FAIL TO OPERATE (REDUNDANCY) >FAIL TO MANUAL>FAIL TO SAFE**
- **DESIGN LUNAR EQUIPMENT & FACILITIES WITH IMBEDDED DIAGNOSTICS**
  - **RAPID INSPECTION, REPAIR, AND UPGRADE**

NASA'S PLANS ON THESE ISSUES NOT KNOWN AT THIS TIME

RISK, PRODUCTIVITY, AND COST MANAGEMENT -2: OPERATIONS

****SHOULD APPLY TO NASA OR PRIVATE INITIATIVE**

- **MAINTENANCE**
  - **DESIGN AND OPERATE FOR PREDICTIVE AND PREVENTIVE MAINTENANCE**
    - **PART SELECTION, TESTING, AND INSPECTION**
    - **PRE-FAILURE PART REPLACEMENT**
  - **DUST MANAGEMENT EMPHASIS IN DESIGN AND OPERATIONS****
- **INVENTORY ALL DISCARDED OR UNUSED MATERIALS FOR FUTURE USE**
  - **TOO VALUABLE TO THROW AWAY****

NASA'S PLANS THESE ISSUES NOT KNOWN AT THIS TIME

RISK, PRODUCTIVITY, AND COST MANAGEMENT -3: PERSONNEL

- LUNAR STAY-TIME
  - PRIVATE INITIATIVE WOULD WANT SETTLERS AS LUNAR EMPLOYEES
    - RETURN COSTS ELIMINATED
- LUNAR WORK CYCLE
  - 12 HOUR SHIFTS, 2 HOUR OVERLAPS
  - 6 DAY WORK WEEKS
    - STAGGERED AFTER 2 MINER-PROCESSORS IN OPERATION
  - 24 DAY LUNAR WORK MONTH
  - 13 LUNAR WORK MONTHS
    - ONE LUNAR MONTH R&R / YEAR AS SOON AS SETTLEMENT PRODUCTION RATES PERMIT
- TERRESTRIAL OPERATIONAL WORK CYCLE
  - DESIGNED TO SUPPORT LUNAR REQUIREMENTS

RISK, PRODUCTIVITY, AND COST MANAGEMENT -4: HEALTH

- **PHYSICIAN PRESENT ANYTIME EIGHT OR MORE PERSONS PRESENT**
  - **EARLY DEVELOPMENT OF LUNAR OCCUPATIONAL MEDICINE CRITERIA**
  - **ON-SITE RESEARCH PROGRAM**
- **INJURY OR ILLNESS TREATED AT THE BASE**
  - **REPLACEMENT OF CRITICAL FUNCTIONS BY TEMPORARY INCREASE IN WORK HOURS OF OTHER INDIVIDUALS**
    - **EARTH-BASED TELE-MEDICAL ASSISTANCE**
- **SOLAR FLARE RISK MANAGEMENT BY DESIGN, DAILY PLANNING, AND FORECASTING (?)**
  - **NOT JUST AN ACTIVE SUN (11 YEAR CYCLE) PROBLEM**

RISK, PRODUCTIVITY, AND COST MANAGEMENT -5: STAFFING

- **CORE STAFFING CONSTRAINTS (EACH 100 KG HELIUM-3/YEAR)**
  - **4 OPERATOR-ENGINEERS PER MINER-PROCESSOR**
  - **4 OPERATOR-ENGINEERS PER VOLATILE REFINERY**
  - **2 GEOLOGIST-MINE PLANNERS**
  - **2 OPERATIONS SUPPORT / PHYSICIANS**
  - **2 OPERATOR-ENGINEERS FOR MAIN BASE PLANNING**
  - **1 OPERATIONS DIRECTOR (SETTLEMENT MANAGER)**
  - **1 EXPLORATION GEOLOGIST / DEP. OPERATIONS DIRECTOR**
  - **16 TOTAL OR TWO SATURN VI LAUNCHES**
- **ADDITIONAL SKILLS WITHIN GROUP**
  - **POWER SYSTEMS**
  - **ENVIRONMENTAL CONTROL**
  - **EMERGENCY MEDICAL TREATMENT**
  - **ELECTRONIC SYSTEMS**
  - **RISK MANAGEMENT**

RISK, PRODUCTIVITY, AND COST MANAGEMENT -6: STAFFING

- **CORE STAFFING CONSTRAINTS (5+ MINER-PROCESSORS)**
  - **4 OPERATIONS SUPPORT PERSONNEL**
    - **OPERATOR-ENGINEERS AND OPERATIONS SUPPORT PERSONNEL CROSS-TRAINED**
    - **PERIODIC ROTATION**
  - **2 SETTLEMENT OPERATIONS SUPPORT ENGINEERS**
  - **2 LONG TERM PLANNING COORDINATORS**
  - **ANCILLARY BUSINESS MANAGERS AS REQUIRED**

- **CORE STAFFING CONSTRAINTS (15+ MINER-PROCESSORS)**
  - **1 DEDICATED SETTLEMENT MANAGER**
  - **2 ADVANCED TRAINING / CAREER TRANSITION MANAGERS**

FUTURE SUIT DESIGN GOALS:

>1/2 THE MASS
>4 TIMES THE MOBILITY
HAND DEXTERITY = NORMAL
ASSISTED GRIP GLOVES
>100 CYCLES BEFORE REFURBISHMENT
VACUUM CONNECT / DISCONNECT

NASA PHOTO

FUTURE ROVER DESIGN GOALS:

CREW DRIVING CONSUMABLES
CONVERSION TO RADIATION SHELTER
INDEFINITE LIFE DESIGN
RESOURCE MAPPING CAPABILITY

NASA PHOTO

RISK, PRODUCTIVITY, AND COST MANAGEMENT -7: SETTLER SELECTION

- **CRITERIA TO CONSIDER**
  - **SKILL MIX AND CROSS-TRAINING**
  - **YOUTH AND TRAINING VS. AGE AND EXPERIENCE**
  - **PHYSICAL CAPABILITY**
  - **MEDICAL RISK ANALYSIS**
  - **PSYCHOLOGICAL RISK ANALYSIS**
  - **PHYSIOLOGICAL AND PSYCHOLOGICAL TOLERANCE TO SPACE ENVIRONMENT**
    - **SPACE STATION TOUR TO WEED OUT 2%WHO DON'T ADAPT ??**
  - **COMMITMENT TO SETTLEMENT**
  - **COMMITMENT TO ON-SITE HEALTHCARE VS. RETURN TO EARTH**

BASE ARCHITECTURE -1
PRE-ACTIVATION REQUIREMENTS

- **SET LUNAR BASE DESIGN GOALS**
  - **INDEFINITE SUPPORT OF HUMAN ACTIVITIES**
  - **NEAR-TERM OXYGEN AND HYDROGEN PRODUCTION**
  - **MID-TERM HE-3 PRODUCTION**
  - **LONG-TERM PRODUCTION OF NEEDED MATERIALS AND FOOD**
  - **ANCILLARY USES OF THE MOON (SCIENCE, TOURISM, ETC.)**

- **INITIAL FREQUENCY OF LAUNCHES TO THE MOON**
  - **ONE PER TWO LUNAR CYCLES (ASSUMES NEW SATURN VI BOOSTER)**
  - **ON-SITE CONSUMABLES SUFFICIENT TO MISS AT LEAST TWO RE-SUPPLY OPPORTUNITIES**

BASE ARCHITECTURE -2
PRE-ACTIVATION REQUIREMENTS

- **EQUIPMENT AND FACILITY DESIGNS**
  - **INDEFINITE LIFE THROUGH ANTICIPATORY MAINTENANCE**
  - **FINALIZED PRIOR TO BASE ACTIVATION**

- **SITE OF FIRST BASE**
  - **ACCESS TO HIGHEST GRADE HE-3 PROVEN RESOURCE**
    - **H_2 CONCENTRATION SECONDARY CRITERION**
      - **H_2 AND H_2O ($O_{2)}$ PRODUCTION CAN OCCUR AT ANY LOCATION**

BASE ARCHITECTURE -3

- **GENERAL ARCHITECTURAL LAYOUT OF THE BASE CORE FINAL BEFORE THE FIRST LANDING**
  - **SUPPORT INITIAL MINING AND PROCESSING ACTIVITIES**
  - **PROVIDE LONG TERM SUPPORT FOR REGIONAL MINING AND ANCILLARY BUSINESSES**

- **LANDING AND LAUNCH OPERATIONS WILL BE LOCATED AND DESIGNED SO AS TO NOT DISRUPT OTHER ACTIVITIES OR OTHER ACTIVITIES**
  - **DUST CONTROL**

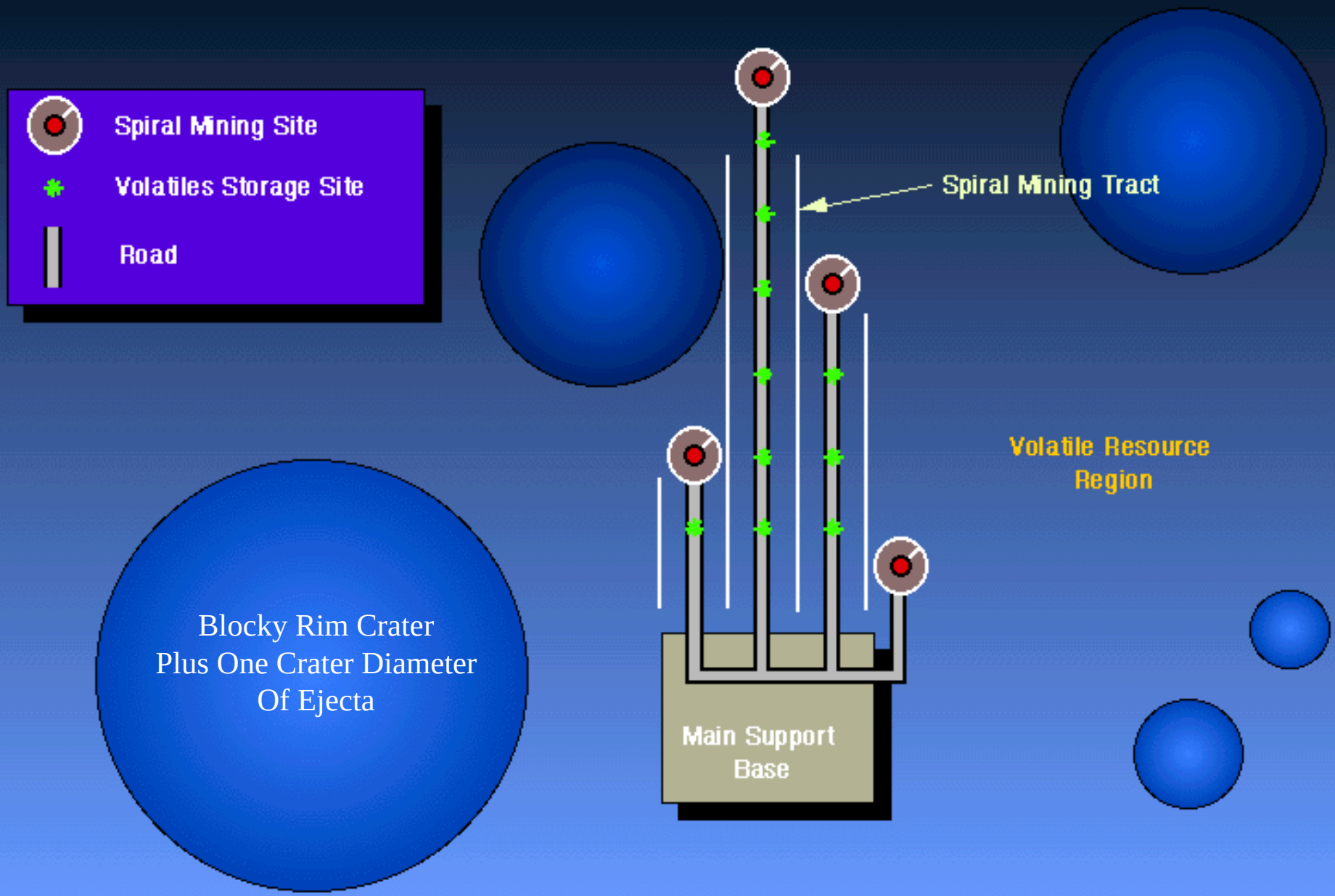
- **ROADS AND WALKWAYS WILL BE STABILIZED**
  - **DUST CONTROL**

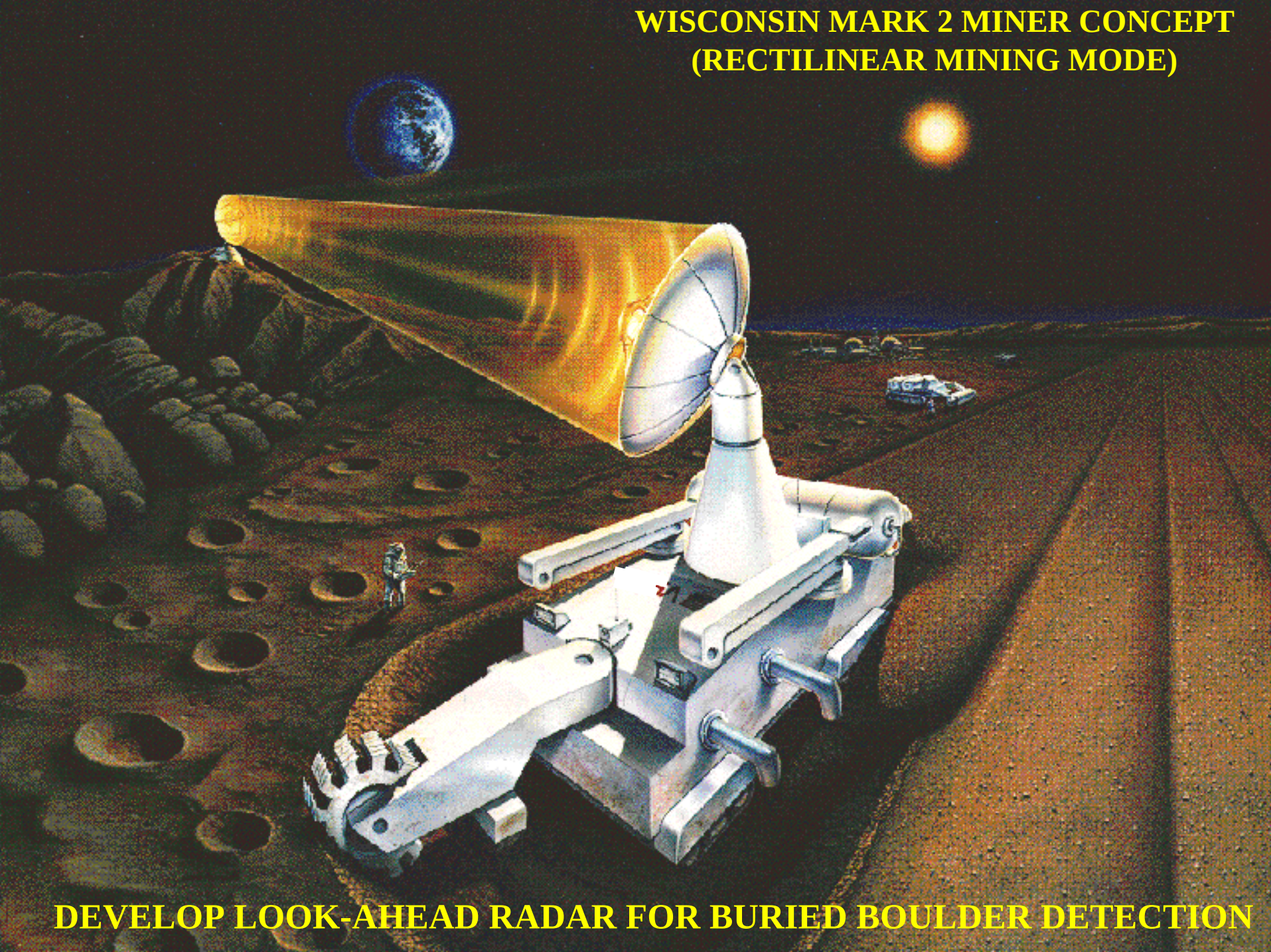
BASE ARCHITECTURE -4

- LANDER PROPULSION MODULES AND RESOURCE TRANSFER MODULES WILL BE ACCESSIBLE TO REFUELING AND LOADING FACILITIES
  - LAND TO BEACON OFFSET
  - RESOURCE TRANSFER MODULES TRADE STUDY
    - LAUNCH MODE
    - MASS PER LAUNCH: VALUE VS. RISK VS. PRODUCTION RATE VS. CONSUMPTION RATE

- APPROPRIATE CRATERS RESERVED FOR CRYOGENIC STORAGE OF LUNAR CONSUMABLES
  - BURIED, INFLATABLE “BALLOONS”
  - PASSIVE, REGOLITH INSULATION
    - PASSIVE, RADIATIVE COOLING TO DEEP SPACE ??

Regional Mining Plan Utilizing Spiral Mining Systems




WISCONSIN MARK 2 MINER CONCEPT
(RECTILINEAR MINING MODE)
DEVELOP LOOK-AHEAD RADAR FOR BURIED BOULDER DETECTION

Spiral Mining System for Lunar Volatiles

Mobile Miner

Solar Thermal Receiver

New Road

VR

HS

PS

SA

Mined Area

New Road

Wheel Track

LP

Old Road

Temporary Road

VR: Volatile refining subsystems
HS: Habitat and crew work section
LP: Launch and landing platform
PS: Power subsystems
SA: Mobile Miner support arm

Solar Concentrators and Reflectors

Crane

Regolith Filled Shield

Sealed SA Bearing

VR HS PS HS VR

SA

Adjustable Skirt

Parking and Storage

Cryogenic Storage Center

Mobility Subsystem (1 of 4)

MARK 2 RE-DESIGN ISSUES -1

1. **SPIRAL VS. LINEAR VS. ?**
   - **COST / KG**
   - **OPERATIONAL RISK**
   - **PAYLOAD MASS TO MOON**
2. **ELECTRICAL POWER SYSTEM**
   - **H_2-0_2-SOLAR CLOSED CYCLE FUEL CELL**
   - **PHOTOVOLTAIC**
   - **SOLAR THERMAL**
   - **FISSION REACTOR**
3. **REGOLITH HEATING SYSTEM (IMPACTS #2 ABOVE)**
   - **SOLAR THERMAL**
   - **MICROWAVE-ELECTRIC**
   - **FISSION THERMAL**

MARK 2 RE-DESIGN ISSUES -2

- **CONSIDERATIONS OF REGOLITH GEOTECHNICAL PARAMETERS**
  - **SPECIFIC GRAVITY**
  - **CONCENTRATION OF FINES (<100 MICR0NS)**
  - **“ROCK”** DISTRIBUTION**
  - **CONCENTRATION OF INDURATED REGOLITH FRAGMENTS**
  - **CONCENTRATION OF FeS (VERY LOW BUT PRESENT)**
  - **COHESIVENESS / INTERNAL FRICTION**
  - **ABRASIVENESS**
  - **HYDROGEN EFFECTS (IF ANY)**
  - **WATER EFFECTS (IF ANY) IN PROCESSOR**
  - **DUST EFFECTS IN PROCESSOR**

****ROCK FRAGMENTS TO LARGE TO BE PROCESSED IN MINER-PROCESSOR**

MARK 2 RE-DESIGN ISSUES -3

1. **PRE-PROCESSING AGITATION LOSSES**
   - **~37% He LOST BETWEEN MOON AND LAB**

2. **PROCESSING SYSTEM**
   - **CRUSHING OF INDURATED FINES - YES OR NO**
   - **SEPARATION OF FINE FRACTION**
   - **RECOVERY OF AGITATION VOLATILE RELEASES**
   - **WASTE HEAT RECOVERY - YES OR NO**

3. **LARGE ROCK OR ROCK FIELD AVOIDANCE**
   - **LOOK-AHEAD RADAR**
   - **SINGLE ROCK REMOVAL - MINER VS. "BULLDOZER"**

MARK 2 RE-DESIGN ISSUES -4

1. **MAINTENANCE IMPACT ON DESIGN**
   - **IMBEDDED DIAGNOSTICS**
   - **ANTICIPATORY COMPONENT REPLACEMENT**
   - **FAIL TO OPERATE, FAIL TO MANUAL, FAIL TO SAFE**
   - **REFURBISHMENT SCHEDULE**
2. **DUTY CYCLE**
   - **MAINTENANCE REQUIREMENTS**
   - **PERSONNEL WORK / REST / R&R CYCLE**
3. **TERRESTRIAL MINING-PROCESSING BENCHMARKS ??**
   - **CONCEPTUAL APPROACHES TO TERRESTRIAL MINING**
   - **ALTERNATIVE, LOW MASS STRUCTURAL MATERIALS**
   - **CONTROLS AND AUTOMATION POTENTIAL**
   - **LONG-TERM MINING RATES**
   - **MAINTENANCE ISSUES**

OPERATIONAL SUPPORT -1

- **POWER PRODUCTION / CONVERSION TRADES STUDIES**
  - **ACTIVATION PHASE:**
    - **SOLAR ENERGY + BATTERIES + RHUs**
    - **SOLAR ENERGY + BATTERIES + RTGs**
    - **H_2 + O_2 FUEL CELL WITH SOLAR RECYCLING OF H_2O**
  - **INITIAL He-3 PRODUCTION PHASE (O_2 AND H_2 BY-PRODUCT):**
    - **SOLAR ENERGY**
    - **H_2 + O_2 FUEL CELL WITH SOLAR RECYCLING OF H_2O**
    - **FISSION REACTOR**
  - **NORMAL PRODUCTION PHASES AND SELF-SUFFICIENT SETTLEMENT:**
    - **FISSION REACTOR**
    - **He-3 FUSION**
    - **SOLAR ENERGY AND FUEL CELLS FOR SPECIAL PURPOSES**

OPERATIONAL SUPPORT -2

- **HUMAN CONSUMABLES FROM LUNAR SOURCES**
  - **AS EARLY AS FEASIBLE:**
    - **PHASE-IN LUNAR PRODUCTION UNTIL INDEFINITE SUPPORT ACHIEVED**
- **REAL-TIME OPERATIONAL / BUSINESS SUPPORT**
  - **BUSINESS MANAGEMENT: INITIALLY EARTH-BASED WITH TRANSITION TO MOON**
  - **MARKETING AND SALES: EARTH-BASED WITH EARTH-MOON COORDINATION**
  - **PRODUCT RECOVERY AND DISTRIBUTION: EARTH-BASED**
  - **RESEARCH AND DEVELOPMENT: EARTH-BASED WITH LONG-TERM TRANSITION TO MOON**
  - **EARTH LAUNCH: EARTH-BASED**
  - **TRANS-LUNAR, MOON LAUNCH AND TRANS-EARTH: MOON-BASED**
  - **BASE AND MINING ACTIVITIES: MOON-BASED**
  - **HEALTHCARE: MOON-BASED**

SATURN VI BOOSTER PAYLOAD MANIFEST -1

SVI-1U*

- MOBILE STATION 1
  - POWER MODULE
  - HABITATION FOR 16
    - OPERATIONS SUPPORT
  - VOLATILE REFINERY
  - RAD-SHIELD ENVELOPE
  - CRYOGENIC STORAGE
  - MOBILITY SYSTEM
- OFF LOADING SYSTEM
- CONSUMABLES
  - POWER START-UP
    - HYDROGEN
    - OXYGEN

SVI-2U

- MINER-PROCESSOR 1
- CONTROL-TRANSFER ARM
- MULTIPURPOSE ROVER 1
  - AGGREGATE SEPARATOR
  - REGOLITH IMPELLER
  - EARTH MOVER
  - EVA CONSUMABLES
  - RESOURCE MAPPING
  - REMOTE RAD-SHIELD
- OFF LOADING SYSTEM
- CONSUMABLES
  - FOOD
  - OXYGEN

*** SVI-1U: SATURN VI UNMANNED LAUNCH**

SATURN VI BOOSTER PAYLOAD MANIFEST -2

SVI-1M**

- SETTLER LANDING MODULE*
  - 2 ENGR / OP FOR M-P
  - 2 ENGR / OP FOR VR
  - 1 GEO / MINE PLANNER
  - 1 OP SUP / PHYSICIAN
  - 1 EXPL GEO / DEP OPS DIR
  - 1 OPS DIRECTOR
- CONSUMABLES MODULE

SVI-2M

- SETTLER LANDING MODULE*
  - 2 ENGR / OP FOR M-P
  - 2 ENGR / OP FOR VR
  - 1 GEO / MINE PLANNER
  - 1 OP SUP / PHYSICIAN
  - 2 ENGR / OP FOR MAIN BASE PLANNING
- CONSUMABLES MODULE

*** DESIGNED AS MODULAR COMPONENT FOR MAIN BASE OR FOR RE-USE**
**** SATURN VI MANNED LAUNCH**

FIRST TWO MANNED MISSIONS OBJECTIVES

SVI-1M

- ACTIVATE ROVER
- FILL RAD-SHIELD ENVELOPE
- ACTIVATIONS
  - POWER MODULE
  - HABITATION MODULE
    - OPERATIONS SUPPORT
  - VOLATILES REFINERY
  - CRYOGENIC STORAGE
  - MOBILITY SYSTEM
- VERIFY RESOURCE GRADE AT MINE SITE 1
- MOVE STATION TO MINE SITE 1

SVI-2M

- MOVE MINER-PROCESSOR & CONTROL-TRANSFER ARM TO MINE SITE 1
- IMBED MINER-PROCESSOR
- CONNECT CONTROL-TRANSFER ARM
- TEST & CALIBRATE MINER-PROCESSOR
  - TEST & CALIBRATE VOLATILES REFINERY
- INITIATE VOLATILES PRODUCTION
- LAY-OUT MAIN SETTLEMENT SITE

SATURN VI BOOSTER PAYLOAD MANIFEST -3

SVI-3U

- MOBILE CRANE / CARRIER
- MAIN BASE INFRASTRUCTURE COMPONENTS
- AGRICULTURAL PRODUCTION COMPONENTS
- MULTIPURPOSE ROVER 2
- REGOLITH WATER STORAGE SYSTEM
- REGOLITH OXYGEN PRODUCTION SYSTEM
- OFF LOADING SYSTEM

SVI-3M

- SETTLER LANDING MODULE
  - 2 ENGR / OP FOR MAIN BASE
  - 2 ENGR / OP FOR FARM
  - 1 GEO / EXPLORATION
  - 1 BASE OPERATIONS SUPERVISOR
  - 1 SCI / AGRI ENGR
  - 1 BASE MGR
- CONSUMABLES MODULE
  - FOOD
  - HYDROGEN
  - OXYGEN

THIRD MANNED MISSION OBJECTIVES

- **MOVE MAIN BASE COMPONENTS TO PLANNED LOCATIONS**
  - **CONSTRUCT REGOLITH RAD-SHIELDS**
- **INTEGRATE 3 MANNED LANDER CABINS WITH MAIN BASE INFRASTRUCTURE**
  - **CONSTRUCT REGOLITH RAD-SHIELDS**
- **MOTHBALL 6 LANDER PROPULSION MODULES**
  - **ENABLE USE OF TANKS FOR INITIAL HYDROGEN & OXYGEN STORAGE**
- **ACTIVATE AGRICULTURAL PRODUCTION SITE**
  - **FILL REGOLITH RAD-SHIELD ENVELOPE**
- **INSTITUTE DISPUTE / CRIME RESOLUTION SYSTEM (POSSIBLE APPROACH)**
  - **SETTLEMENT MANAGER FINAL ADMINISTRATIVE AUTHORITY AFTER PEER RECOMMENDATION**
  - **APPEAL THROUGH CIVIL COURTS ON EARTH IF APPROVED BY MAJORITY OF SETTLERS**

COST-TRADE STUDIES

- **MINE PLANNING AND FACILITY DESIGNS WITH EXISTING DATA BASE VS. OBTAINING MORE DATA**
- **LAUNCH RATES VS. CREW OBJECTIVES VS. CREW SIZE DURING ACTIVATION**
- **ESTIMATED COST / TONNE COMPARING MINING STRATEGIES**
- **PERCENTAGE MINABLE REGOLITH LEFT UNMINED VS. MARGINAL COSTS TO MINE**
- **USE OF SUPPLEMENTAL EQUIPMENT, E.G., BULLDOZERS TO CLEAR BOULDER FIELDS VS. MINE AROUND**
- **BALANCE BETWEEN EXTRACTION AND REFINING AND SHIPMENT MASS AND STORAGE**
- **CHEMICAL VS. ELECTROMAGNETIC LAUNCH TO EARTH**
- **ROBOTIC VS. TELE-ROBOTIC VS. CREW ASSISTED OPERATIONS**
- **STORAGE VS. THROW-AWAY WITH RESPECT TO BY-PRODUCTS**
- **LOGISTICAL SUPPORT COSTS: IMPORTS VS. RAPID DEVELOPMENT OF LUNAR RESOURCES**

AGRICULTURAL RESEARCH -1

- **HIGH PRIORITY ACTIVITY**
  - **REDUCE COST OF BASE SUPPORT**
  - **DEMONSTRATE SELF-SUFFICIENCY**
- **LIGHTING DESIGN**
  - **PROTECT CROPS FROM RADIATION**
  - **MAXIMIZE USE OF SOLAR ENERGY**
- **HYDROPONICS VERSUS “TRADITIONAL” TECHNIQUES**
- **REQUIRED NUTRIENTS**
  - **LUNAR SOURCES**
- **PLANT / ATMOSPHERE / HABITAT SYSTEM**
  - **MINIMIZE REQUIRED CONSUMABLE AUGMENTATION**

AGRICULTURAL RESEARCH -2

- SOIL AND WATER ADDITIVES AS FUNCTION OF TIME
  - ORGANIC WASTE, WATER AND CARBON DIOXIDE RECYCLED
  - LUNAR NUTRIENTS SOURCES
    - REGOLITH
    - PYROCLASTICS
    - KREEP
- EVALUATE EXPORT ECONOMICS
  - SPACE STATIONS
  - DEEP SPACE MISSIONS
  - ANCILLARY SUPPORT ACTIVITES

ANCILLARY SUPPORT ACTIVITIES

- **LUNAR AND PLANETARY SCIENCE STATION**
- **SOLAR SYSTEM OBSERVATORY**
- **BASIC PHYSICS RESEARCH CENTER**
- **FAR-SIDE RADIO AND OPTICAL OBSERVATORY**
- **TERRESTRIAL METEORLOLGY CENTER**
- **DEEP SPACE MISSION OPERATIONS CENTER**
- **ONE-SIXTH GRAVITY SPACE PHYSIOLOGY RESEARCH CENTER**
- **ONE/SIXTH GRAVITY MATERIALS RESEARCH CENTER**
- **TOURIST FACILITY**
- **ARCHIVAL FACILITY**

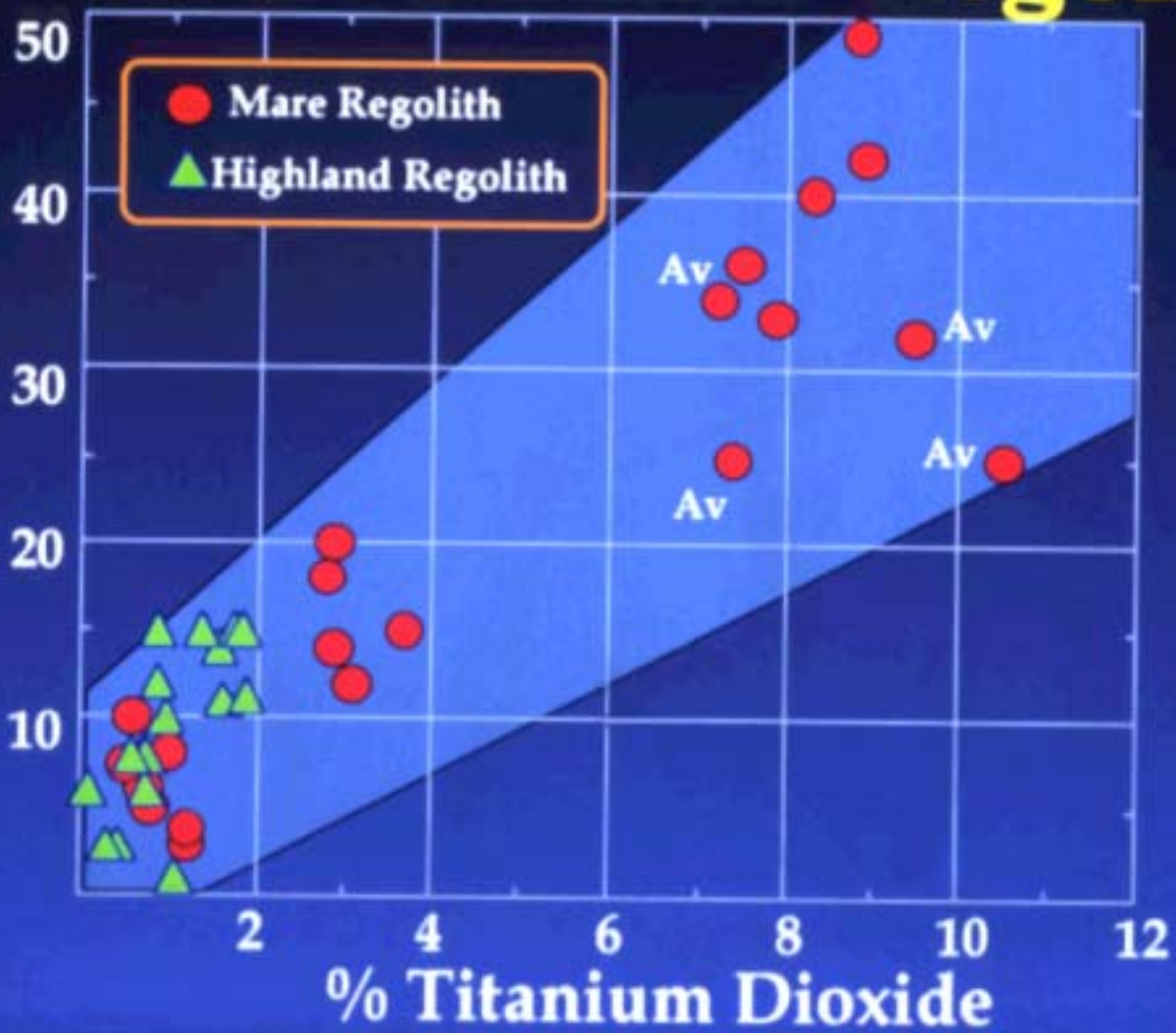
“CULTURAL” DESIGN CONSIDERATIONS -1

- **HABITAT AND INDOOR WORKING FACILITIES PERSONNEL FRIENDLY**
  - **ELECTRONIC, REALTIME WINDOWS**
  - **PIPED IN NATURAL LIGHT**
  - **PRIVACY AREAS**
  - **PERSONAL GARDEN PLOTS**
  - **INDIVIDUAL AND PRIVATE VOICE AND ELECTRONIC COMMUNICATIONS BACK TO EARTH**
  - **INTERNAL RECREATION FACILITY**
- **PLAN FOR EXTERIOR RECREATION**
  - **ADDITIONAL DEMAND ON SPACE SUIT LONGEVITY AND RELIABILITY**

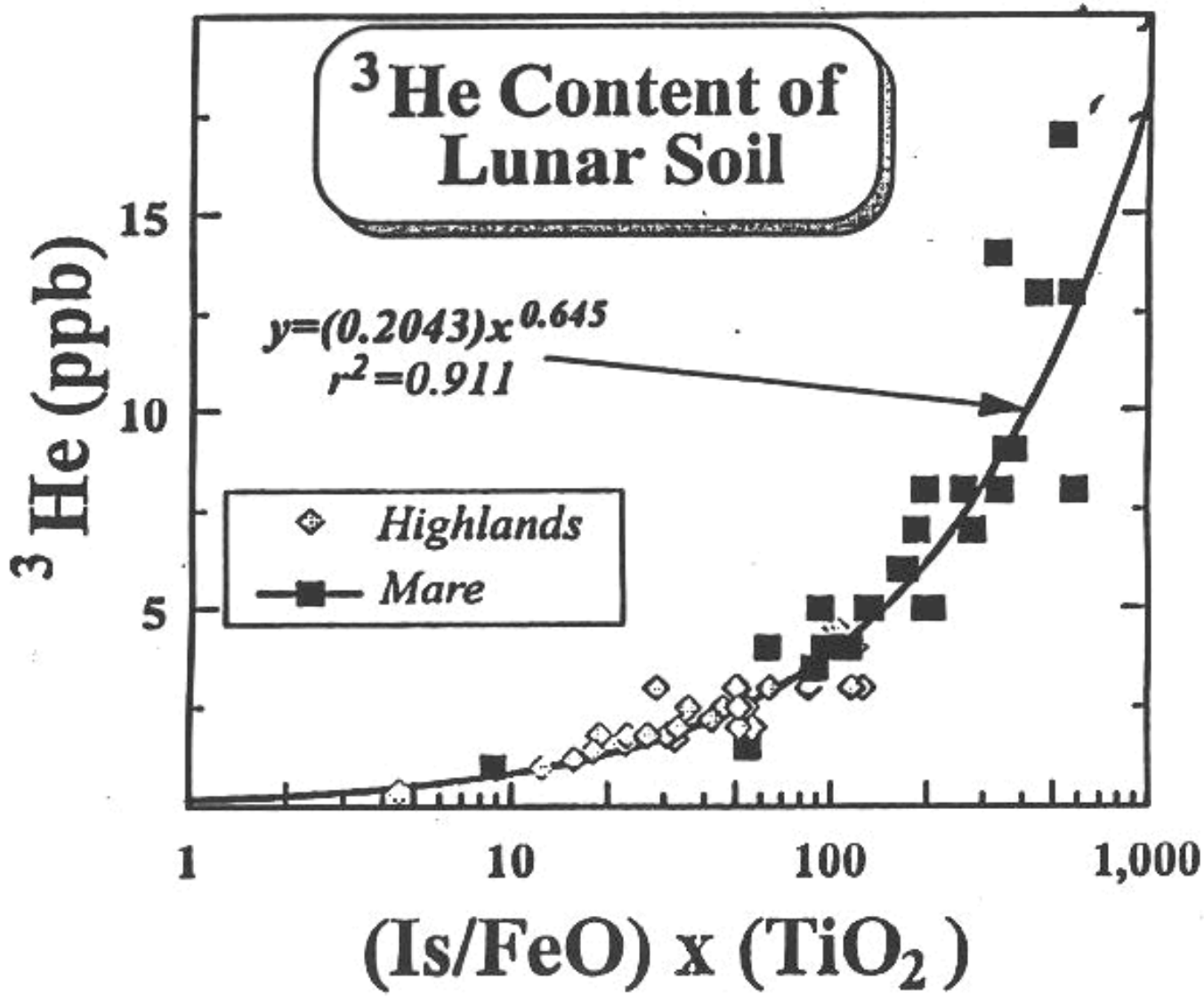
“CULTURAL” DESIGN CONSIDERATIONS -2

- **DETERMINE LONG TERM SUITABILITY OF 1/6 GRAVITY FOR INDIVIDUALS AND FAMILIES**
  - **BIOMEDICAL RESEARCH IN LONG TERM EFFECTS**
  - **BIOMEDICAL RESEARCH IN CHILD PHYSICAL DEVELOPMENT**
  - **BIOMEDICAL RESEARCH IN OCCUPATIONAL MEDICAL PRACTICE**
  - **RE-ADAPTATION PROTOCOL FOR RETURN TO EARTH**
- **FINANCIAL / POLITICAL INCENTIVES FOR ENTERPRISE OWNERSHIP**
  - **STOCK AND STOCK OPTIONS**
  - **GOVERNANCE REPRESENTATION**
  - **LONG TERM PLAN FOR SELF-GOVERNANCE OF SETTLEMENT**
  - **SETTLER-FUNDED “RETURN TO EARTH” INSURANCE ?**

Correlation of Helium Content With TiO2 in Lunar Regolith



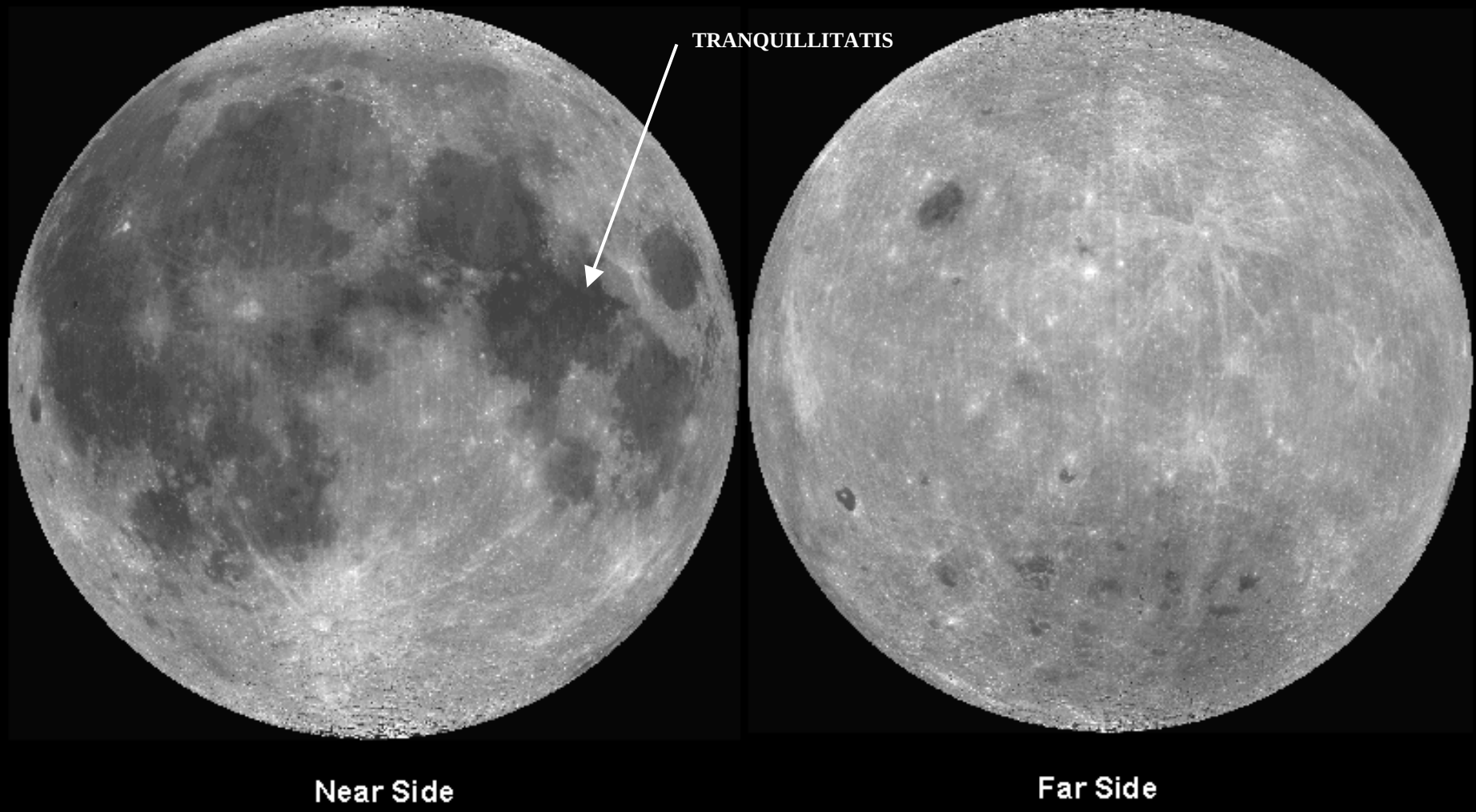
The Concentration of Helium-3 Correlates Quite Well With the Product of Maturity and Ti Content

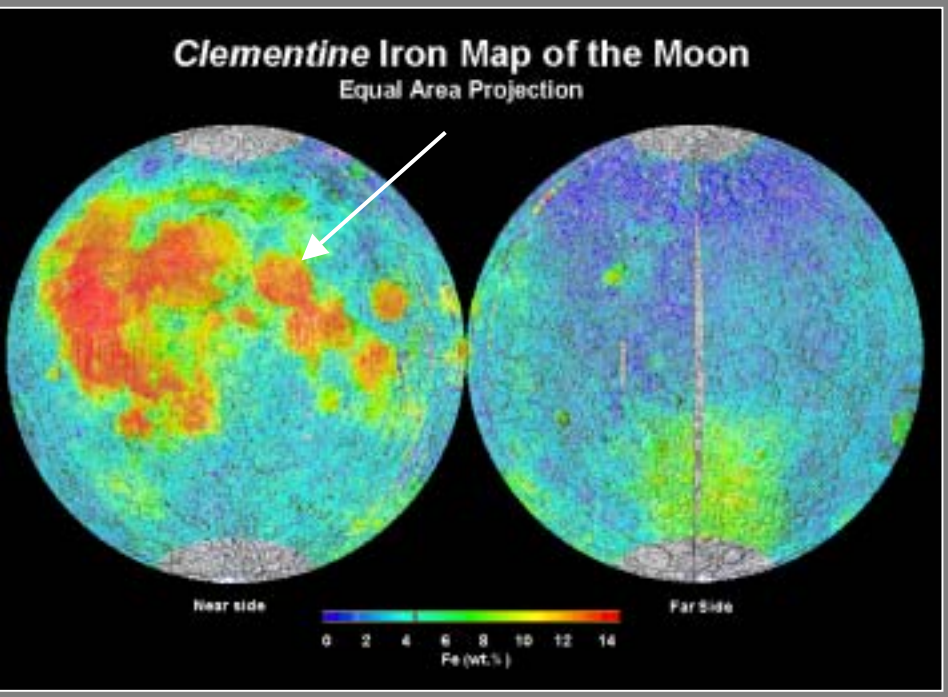


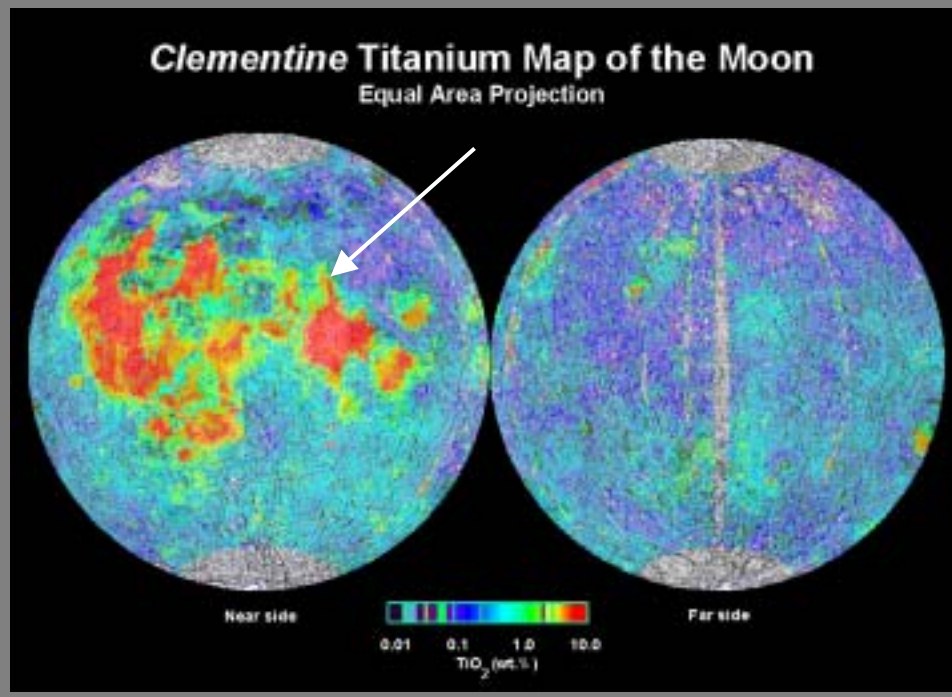
Source: L. A. Taylor, p. 49 in 2nd Wisconsin Symposium on Helium-3 and Fusion Power, 1993

Clementine Global Albedo Images

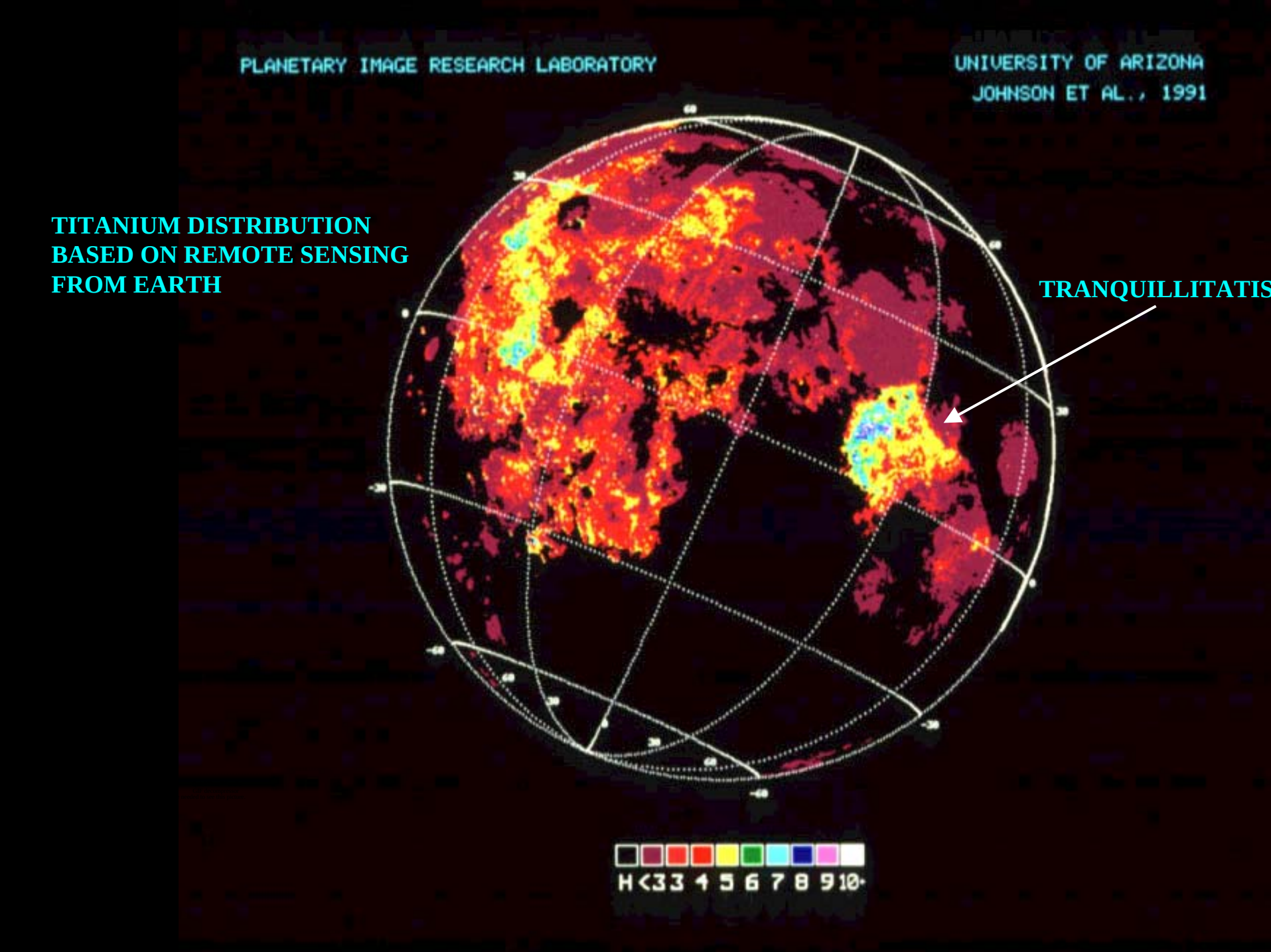
(750 nm filter)

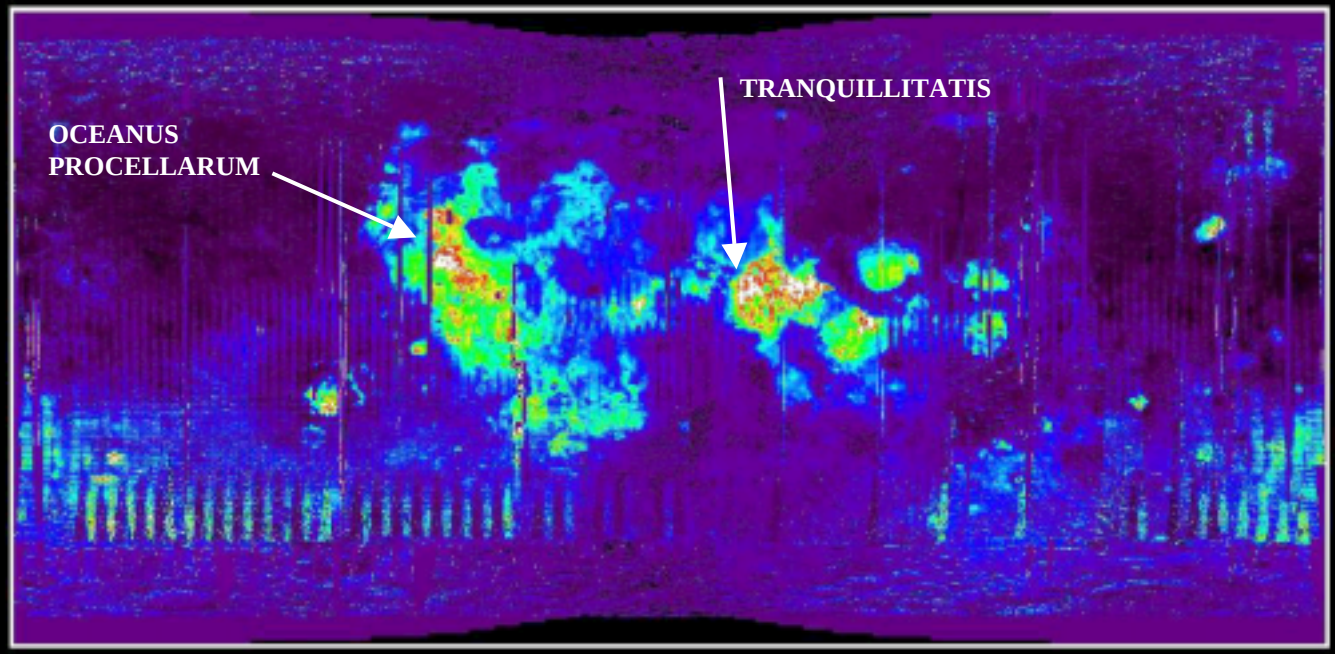






ARROW POINTS TO SERENITATIS BASIN.
NOTE THAT CENTER IS IRON-RICH BUT TITANIUM-POOR

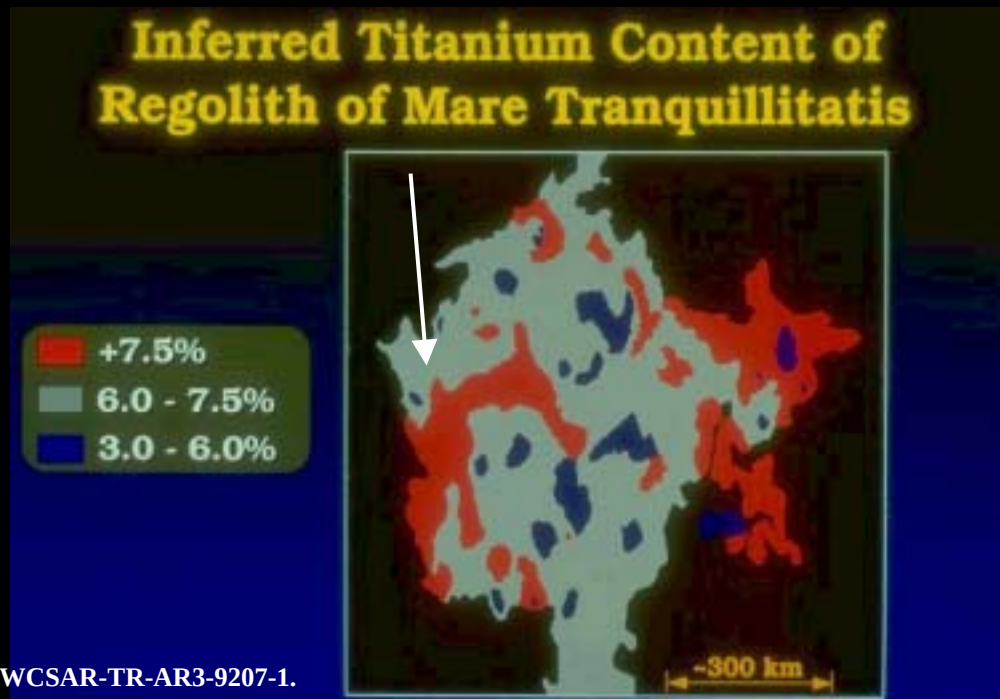

PLANETARY IMAGE RESEARCH LABORATORY
UNIVERSITY OF ARIZONA
JOHNSON ET AL., 1991
TITANIUM DISTRIBUTION
BASED ON REMOTE SENSING
FROM EARTH
TRANQUILLITATIS
H<3 3 4 5 6 7 8 9 10+



Estimated Helium-3 Abundance

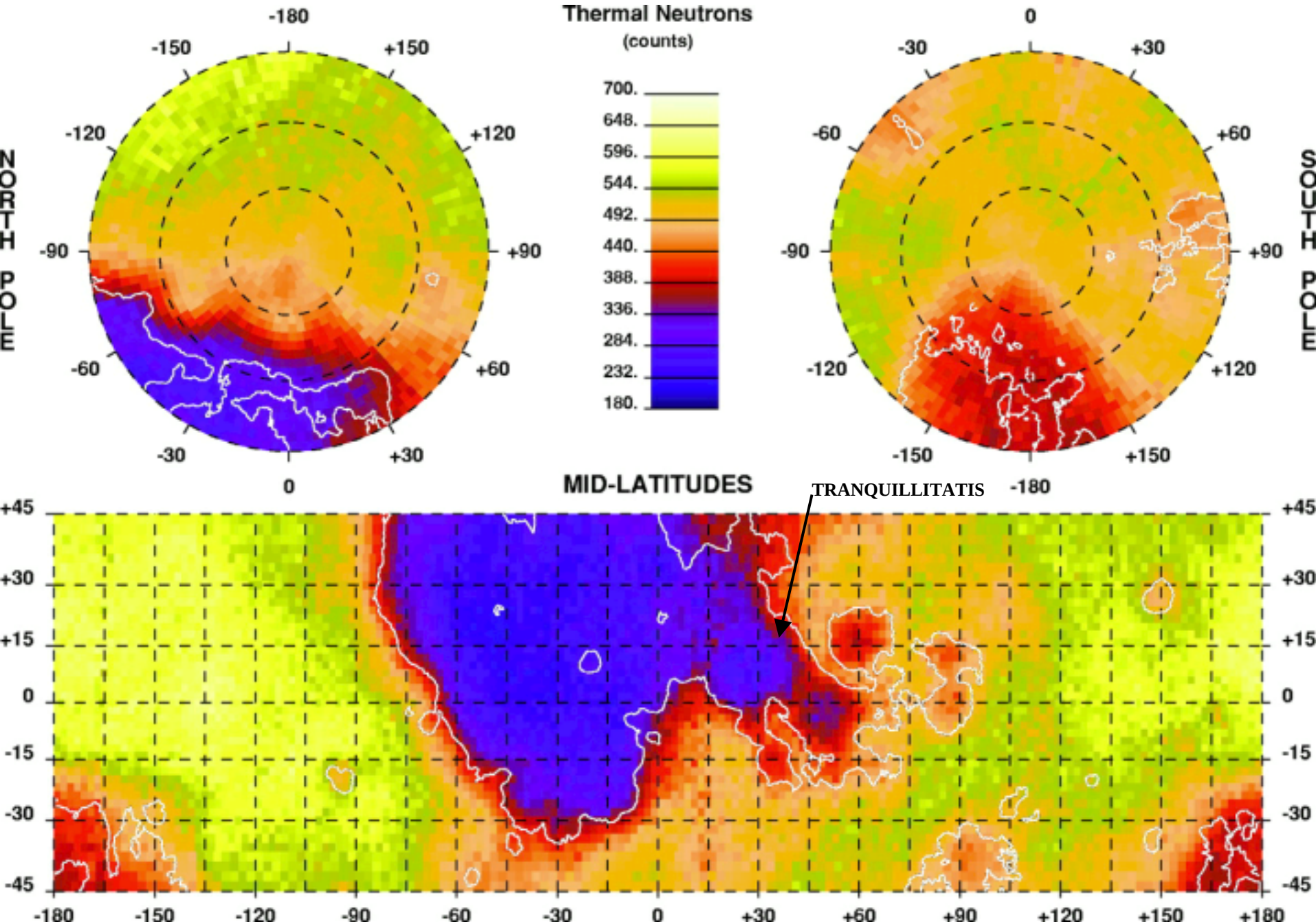
ARROWS INDICATE MAIN AREA OF AGREEMENT

JOHNSON, J.R., SWINDEL, T.D., AND LUCEY, P.G., 1999, GEOPHYSICAL RESEARCH LETTER, 26, 3, 385-388.

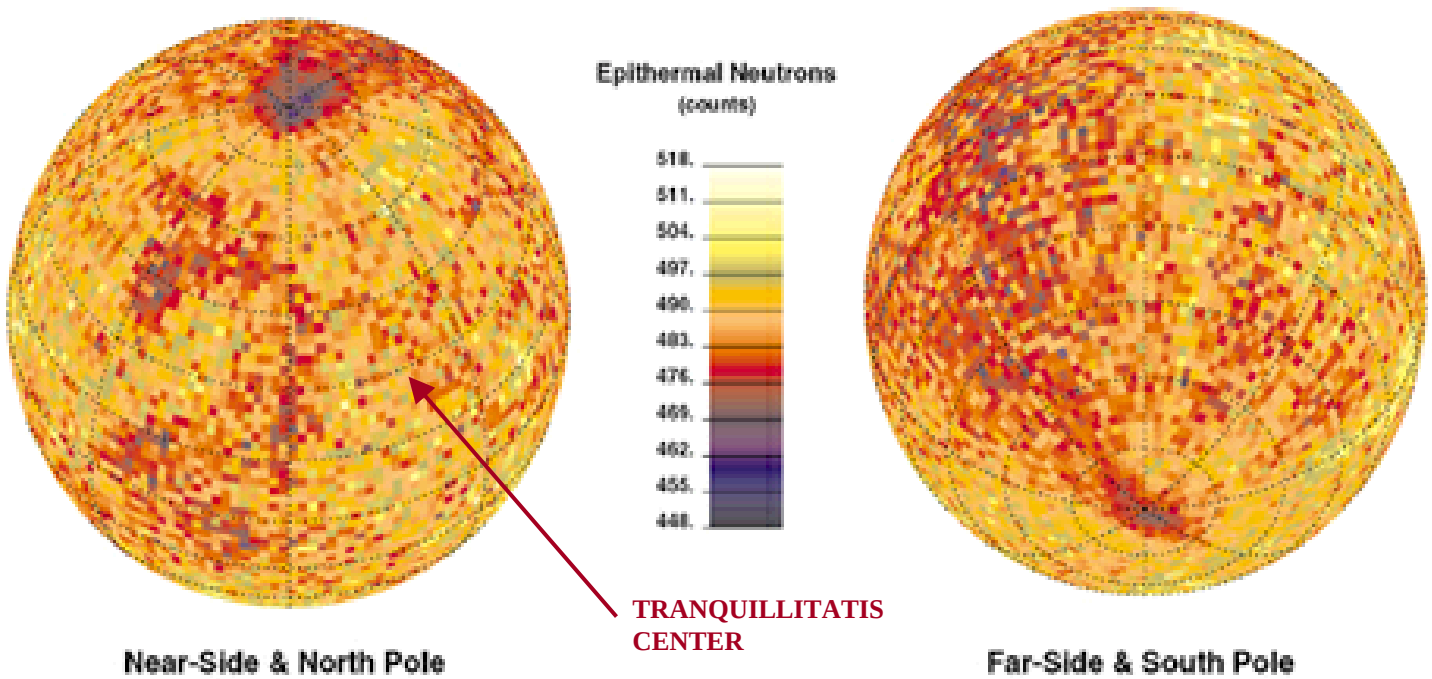


CAMERON, E.N., 1992, TECHNICAL REPORT, WCSAR-TR-AR3-9207-1.

LUNAR PROSPECTOR



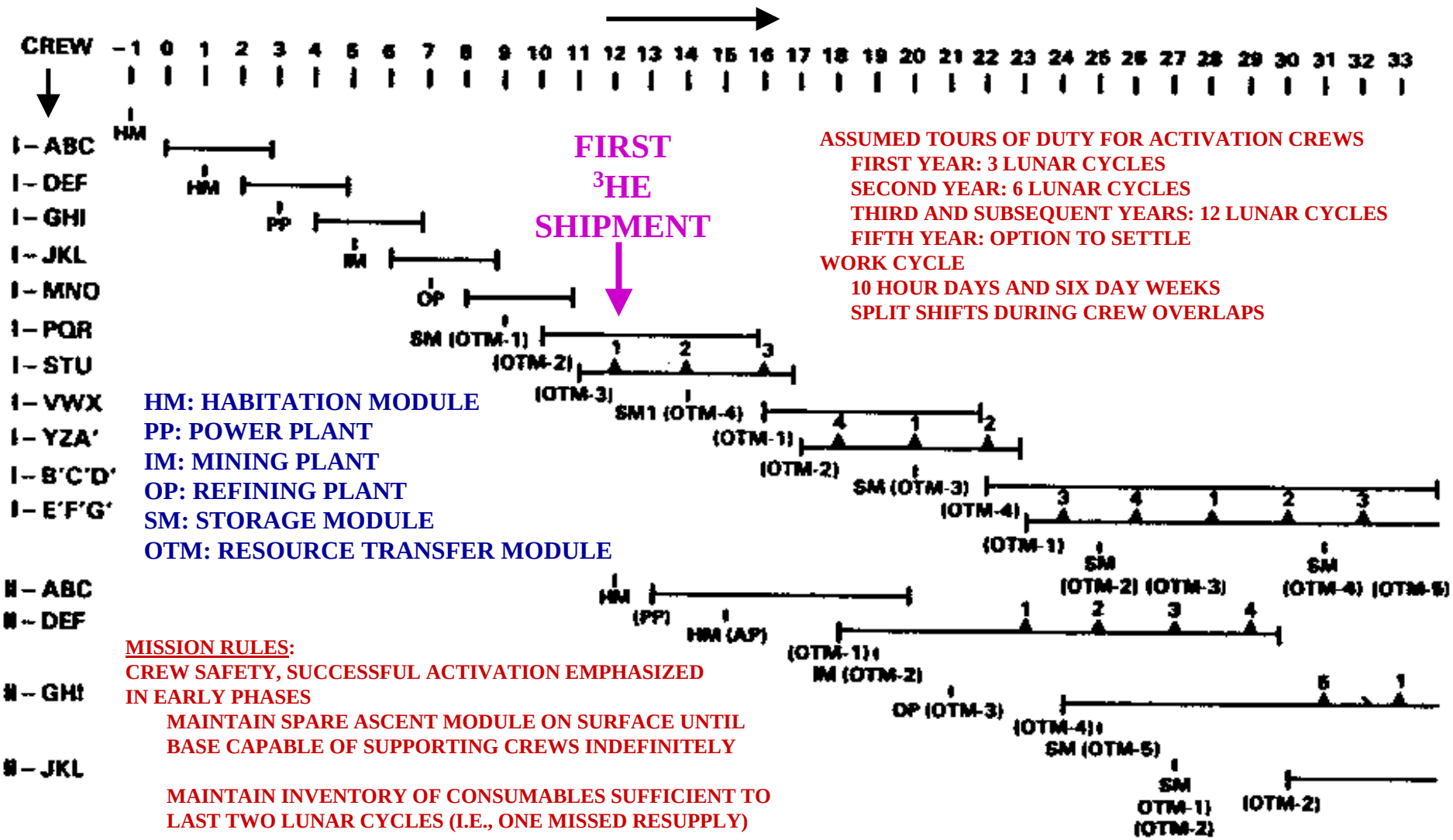
Medium Energy Neutron Distribution
Lunar Prospector



Los Alamos National Laboratory

NOTE: REDUCTION IN NEUTRON COUNT IS MEASURE OF HYDROGEN DISTRIBUTION

SUMMARY TIMELINE
(LUNAR CYCLES FROM FIRST CREW LANDING)



FIRST ^{3}HE SHIPMENT

HM: HABITATION MODULE
PP: POWER PLANT
IM: MINING PLANT
OP: REFINING PLANT
SM: STORAGE MODULE
OTM: RESOURCE TRANSFER MODULE

ASSUMED TOURS OF DUTY FOR ACTIVATION CREWS
- FIRST YEAR: 3 LUNAR CYCLES
- SECOND YEAR: 6 LUNAR CYCLES
- THIRD AND SUBSEQUENT YEARS: 12 LUNAR CYCLES
- FIFTH YEAR: OPTION TO SETTLE

WORK CYCLE
- 10 HOUR DAYS AND SIX DAY WEEKS
- SPLIT SHIFTS DURING CREW OVERLAPS

MISSION RULES:
CREW SAFETY, SUCCESSFUL ACTIVATION EMPHASIZED IN EARLY PHASES
- MAINTAIN SPARE ASCENT MODULE ON SURFACE UNTIL BASE CAPABLE OF SUPPORTING CREWS INDEFINITELY
- MAINTAIN INVENTORY OF CONSUMABLES SUFFICIENT TO LAST TWO LUNAR CYCLES (I.E., ONE MISSED RESUPPLY)