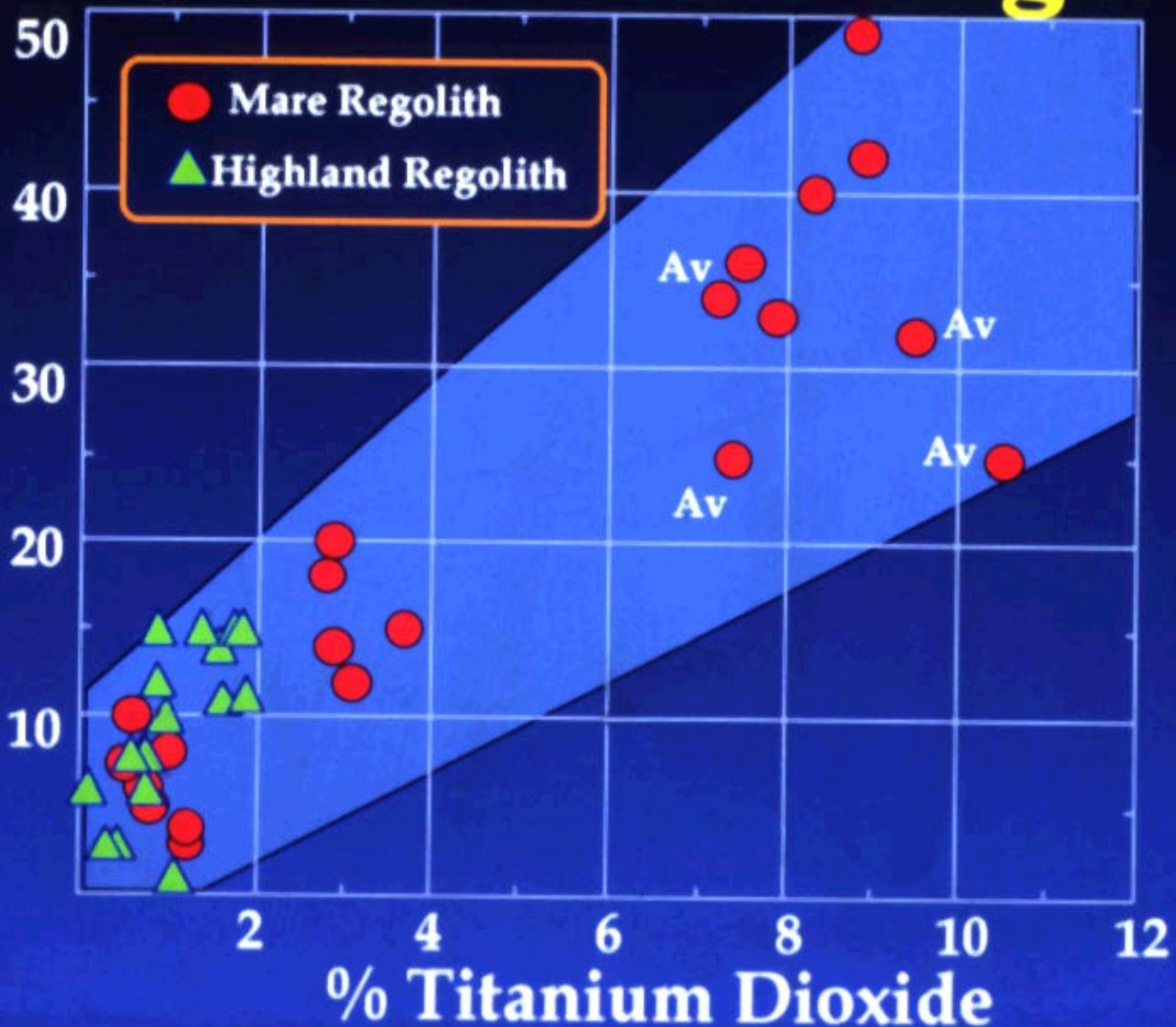
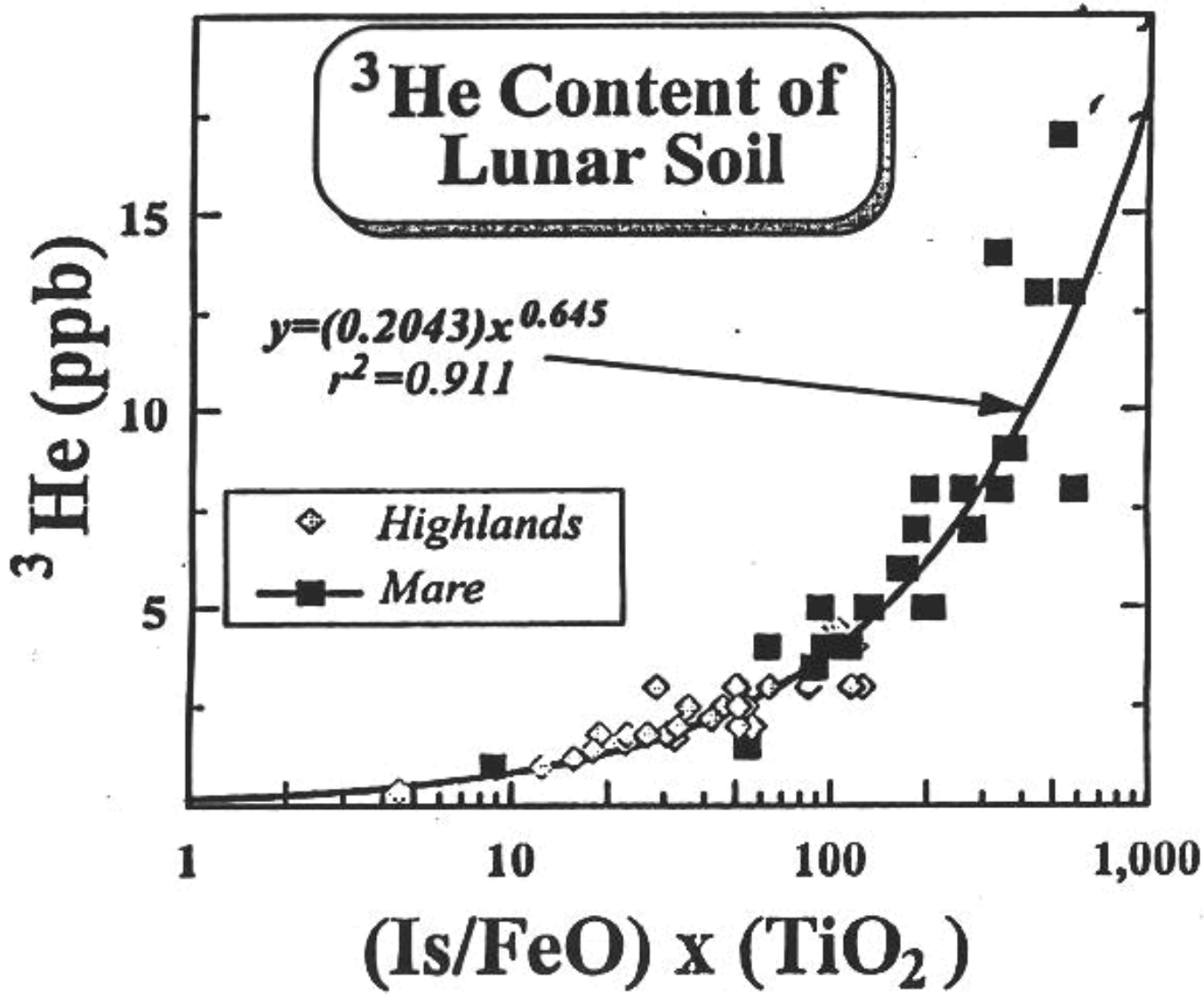
"BUSINESS" APPROACH TO LUNAR BASE ACTIVATION

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

Correlation of Helium Content With TiO2 in Lunar Regolith



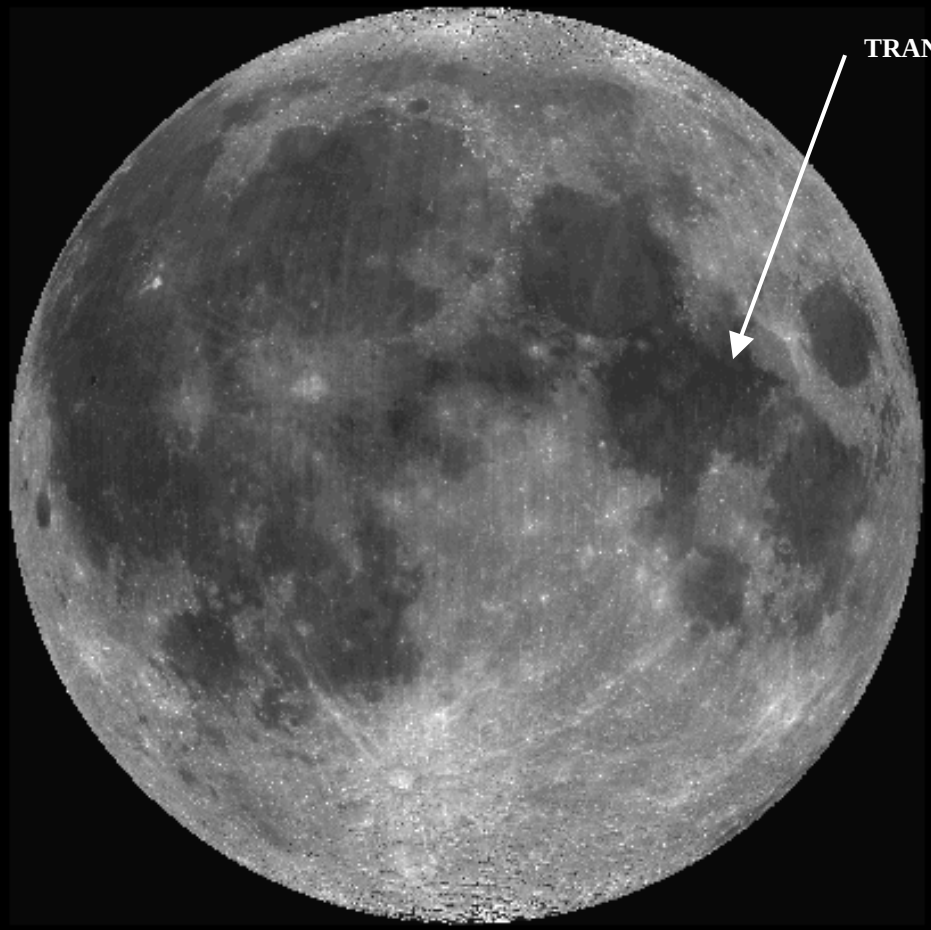
The Concentration of Helium-3 Correlates Quite Well With the Product of Maturity and Ti Content



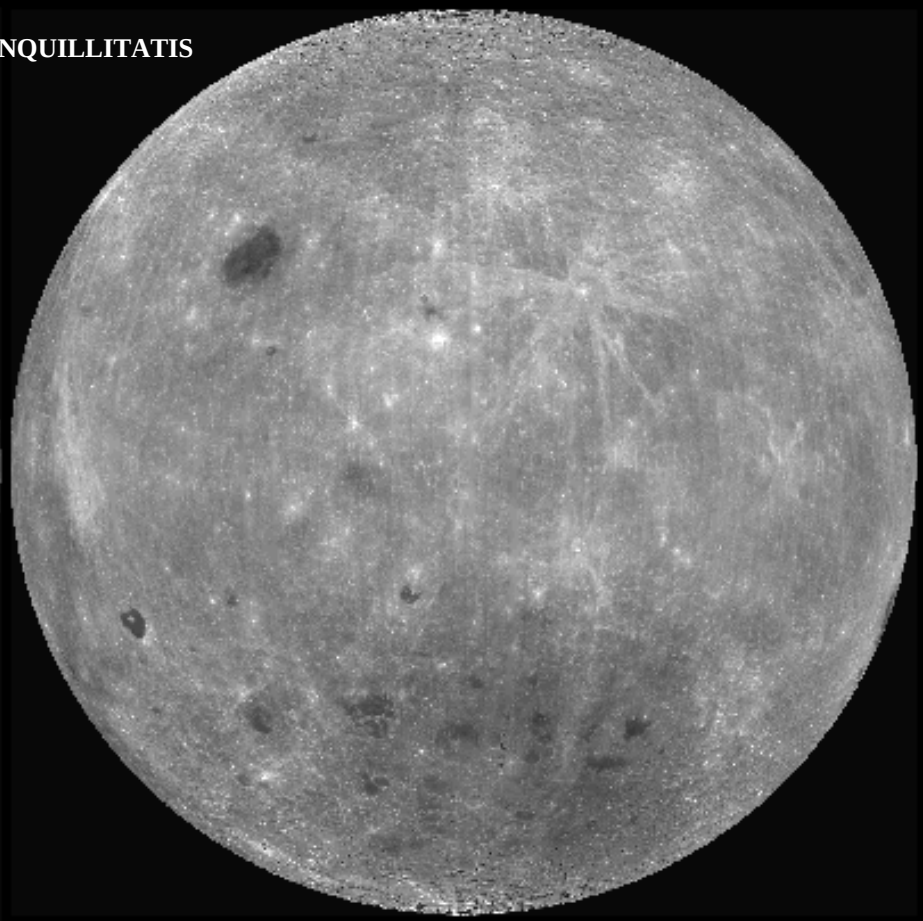
Source: L. A. Taylor, p. 49 in 2nd Wisconsin Symposium on Helium-3 and Fusion Power, 1993

Clementine Global Albedo Images

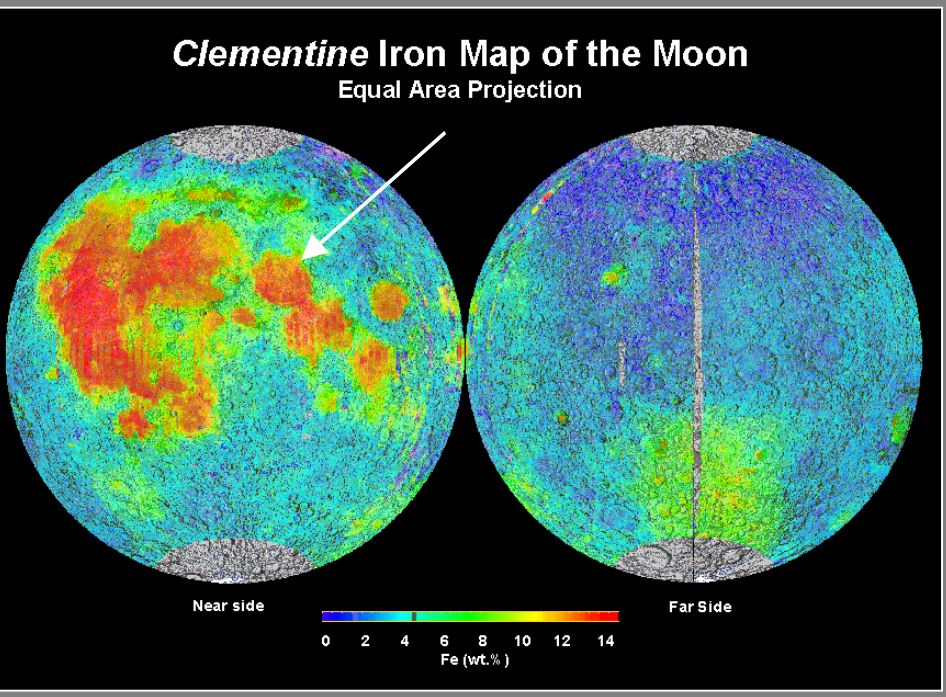
(750 nm filter)

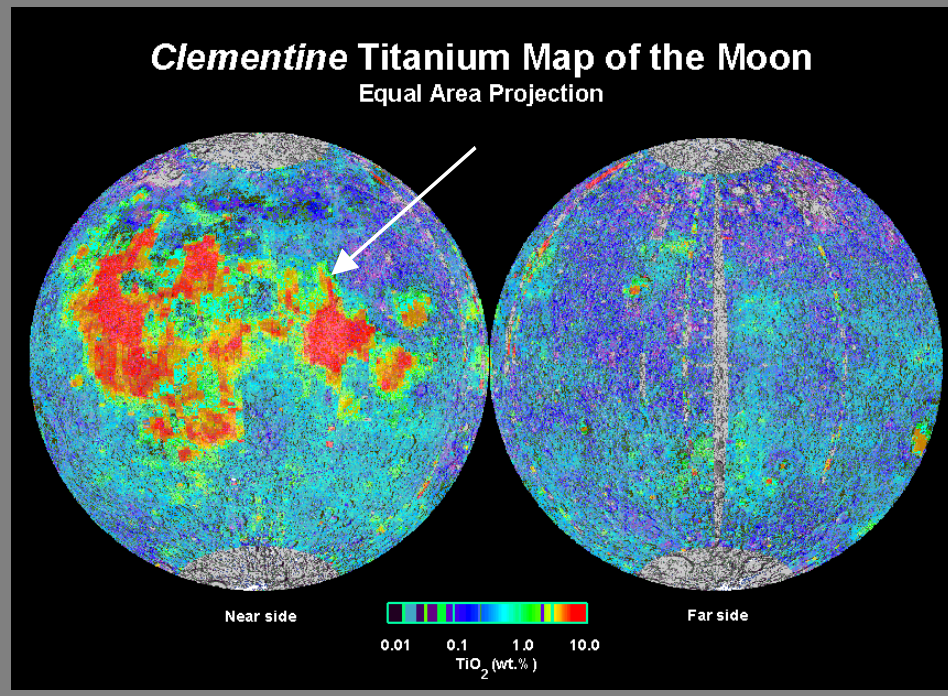


Near Side



Far Side





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

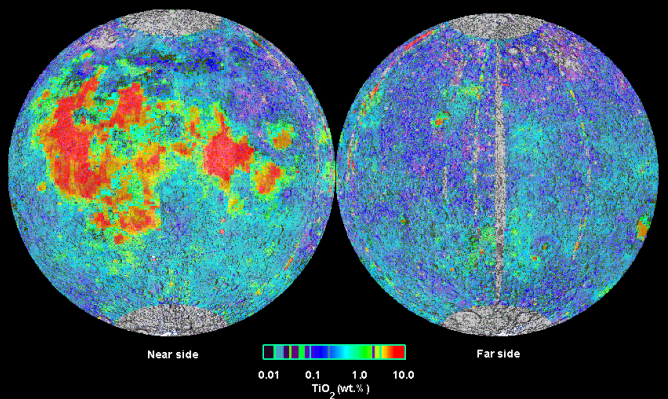
TITANIUM DISTRIBUTION BASED ON REMOTE SENSING FROM EARTH

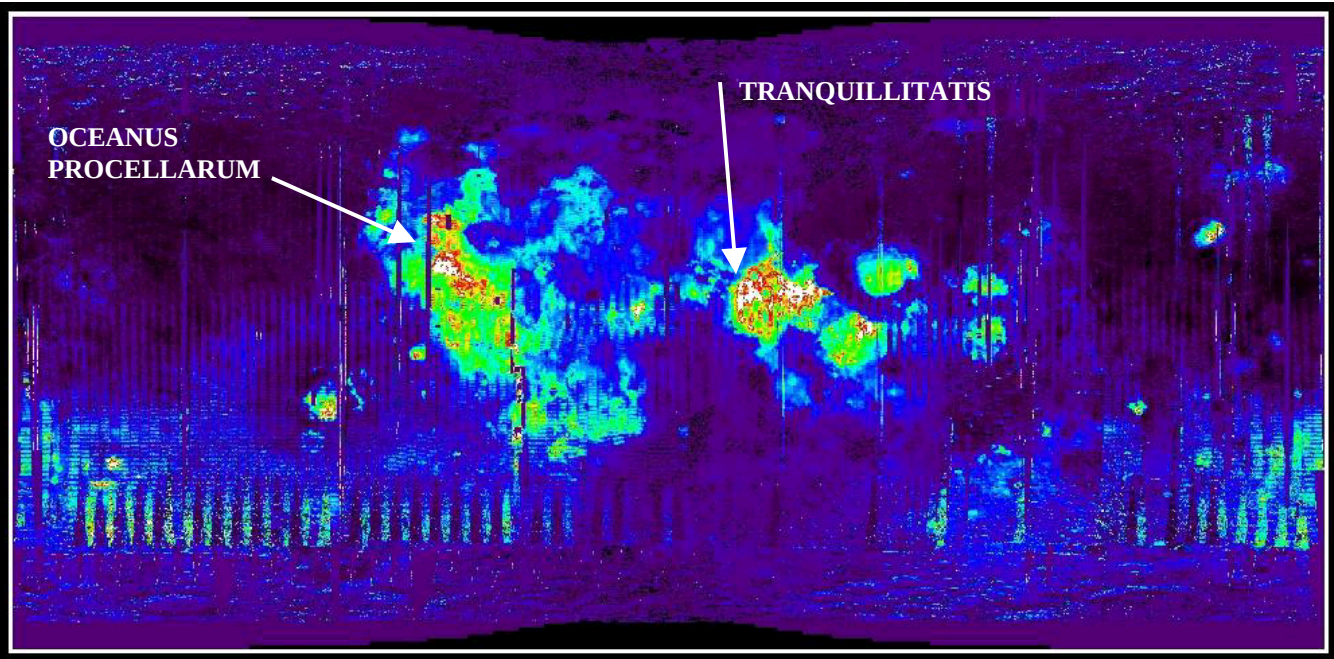
TRANQUILLITATIS

H <3 3 4 5 6 7 8 9 10+

Clementine Titanium Map of the Moon

Equal Area Projection

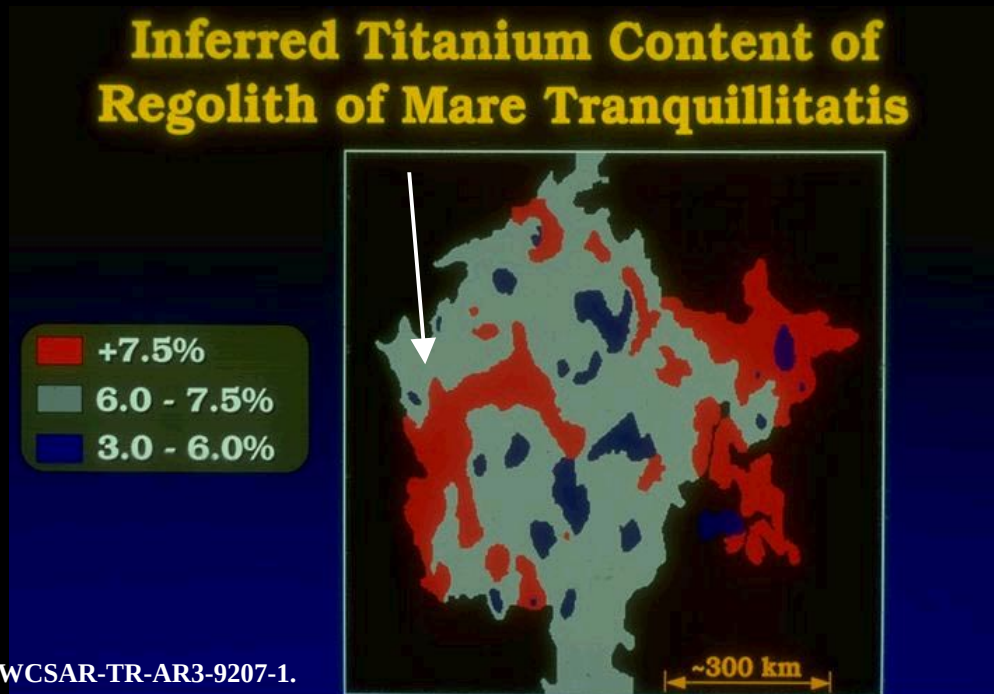




Estimated Helium-3 Abundance

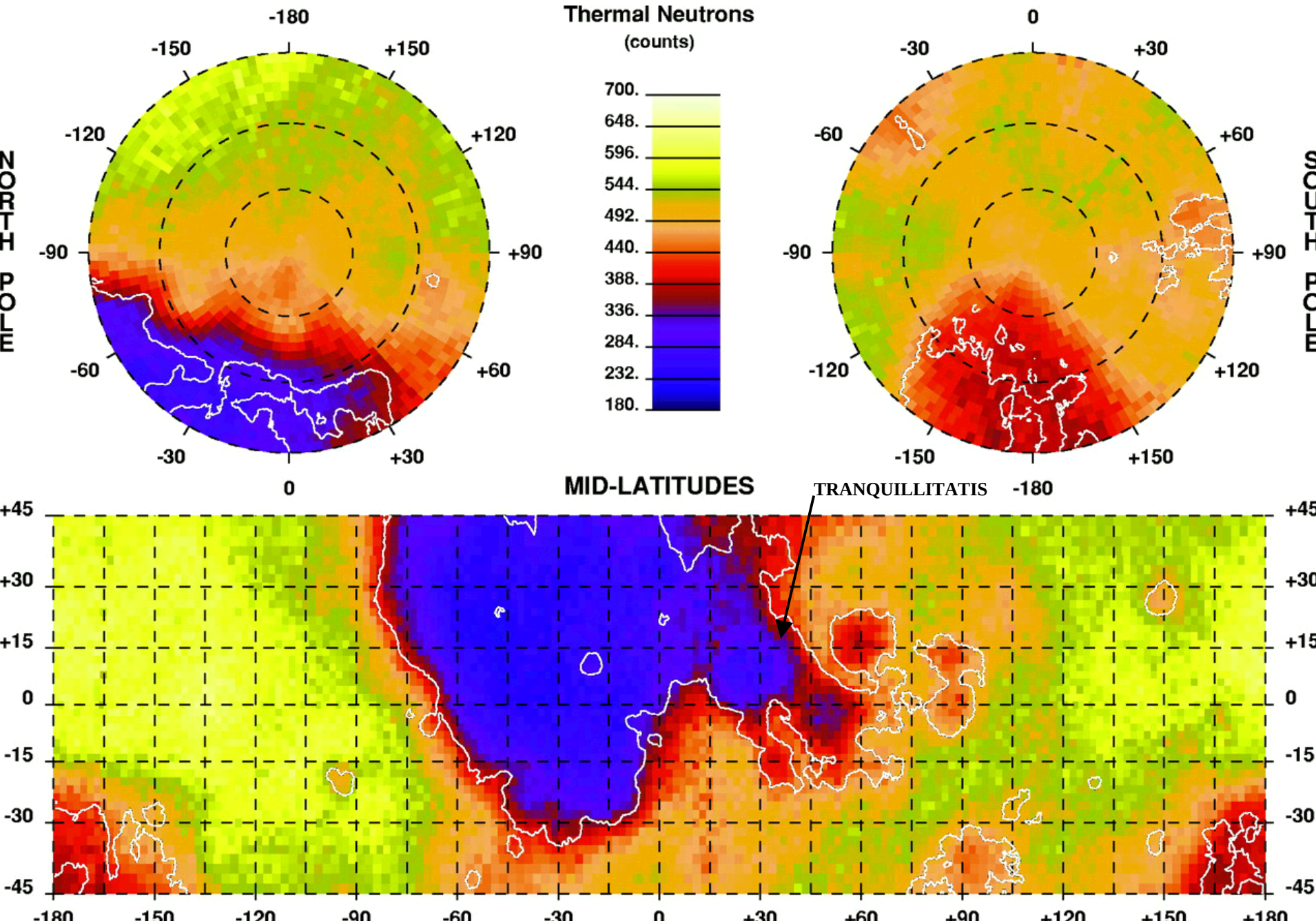
ARROWS INDICATE MAIN AREA OF AGREEMENT

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

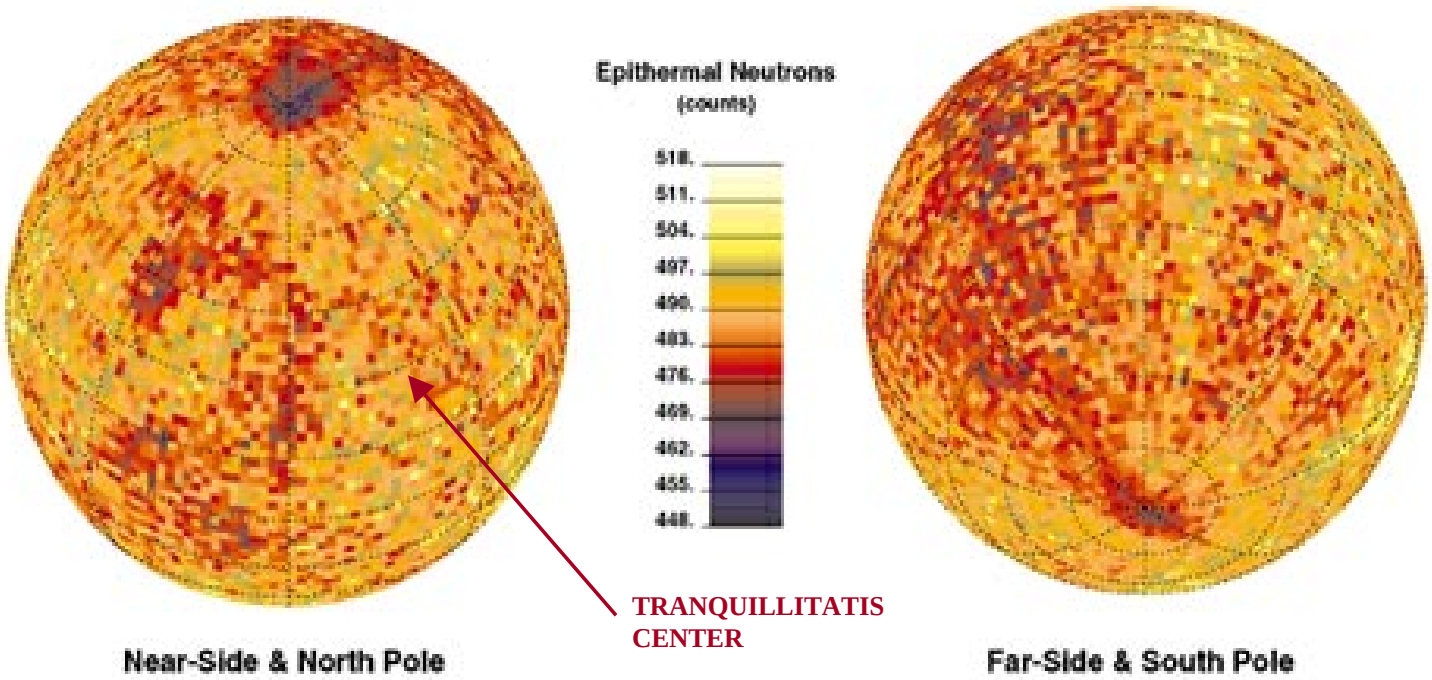


CAMERON, E.N., 1992, TECHNICAL REPORT, WCSAR-TR-AR3-9207-1.

LUNAR PROSPECTOR



Medium Energy Neutron Distribution
Lunar Prospector



Los Alamos National Laboratory

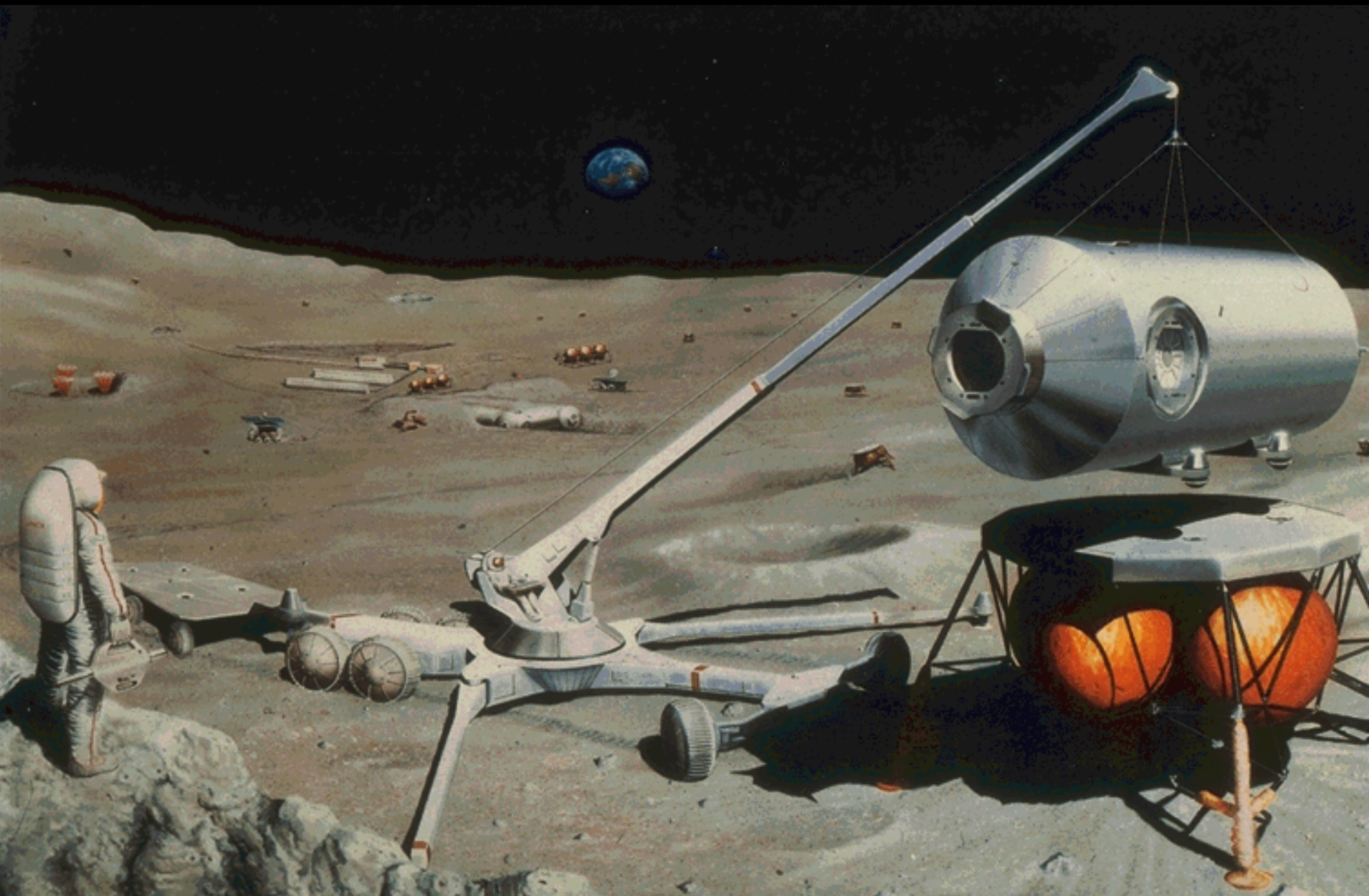
NOTE: REDUCTION IN NEUTRON COUNT IS MEASURE OF HYDROGEN DISTRIBUTION

SATURN VI VS. SATURN V:
<$2000/KG TO THE MOON VS. $70,000
100 TONNES TO THE MOON VS. 44 TONNES
PARTIALLY RE-USABLE VS. EXPENDABLE
COMPARABLE RELIABILITY (~100%)
LONG TERM PRODUCTION VS. FIXED NUMBER
LAUNCH SITE PRIVATE VS. PUBLIC
NO LONG TERM STAND DOWNS AS WITH APOLLO

SOMETHING WITH MORE CAPABILITY THAN APOLLO FOR LUNAR OPERATIONS

NASA PHOTO

ARTIST'S CONCEPTION OF LUNAR BASE ACTIVATION
(NOTE USE OF REGOLITH TO COVER HABITATS)
NASA ART



RISK AND PRODUCTIVITY MANAGEMENT -1

- NO LONG TERM STAND-DOWNS IN LAUNCHES TO MOON
  - DESIGN CRITERION
- LUNAR EQUIPMENT DESIGN
  - FAIL TO OPERATE(BUILT IN REDUNDANCY) >FAIL TO MANUAL>FAIL TO SAFE
- DESIGN LUNAR FACILITIES WITH IMBEDDED DIAGNOSTICS
  - RAPID INSPECTION, RAPID REPAIR, AND RAPID UPGRADE
- MAINTENANCE
  - DESIGN AND OPERATE FOR PREDICTIVE AND PREVENTIVE MAINTENANCE
    - VIBRATION, ULTRASOUND, ELECTRICAL, X-RAY, ETC., TESTING AND INSPECTION
    - PRE-FAILURE PART REPLACEMENT BASED ON TEST AND DESIGN-LIFE PREDICTIONS
  - DUST MANAGEMENT EMPHASIS IN DESIGN AND OPERATIONS
- INVENTORY ALL DISCARDED OR UNUSED MATERIALS FOR FUTURE USE
  - TOO VALUABLE TO THROW AWAY FOREVER

RISK AND PRODUCTIVITY MANAGEMENT -2

- PHYSICIAN ON CREW ANYTIME SIX OR MORE PERSONS PRESENT
- INJURY OR ILLNESS TREATED AT THE BASE
  - REPLACEMENT BY EXTENSION OF TOUR OF ANOTHER QUALIFIED INDIVIDUAL
- SOLAR FLARE RISK MANAGEMENT BY DESIGN, PLANNING AND FORCASTING
- IMPROVE SPACE SUITS RELATIVE TO APOLLO
  - 1/2 THE WEIGHT
  - 4 TIMES THE HAND AND OVERALL MOBILITY
  - 100 TIMES THE OPERATIONAL LIFE OF THE APOLLO SUITS
  - ROUTINE VACUUM CONNECT / DISCONECT TO CONSUMABLES
- ADD CAPABILITY TO LUNAR ROVERS
  - SOLAR PARTICLE EVENT PROTECTION
  - CREW CONSUMABLES SUPPLIES
- DEVELOP LOOK-AHEAD RADAR FOR BURIED BOULDER DETECTION


FUTURE SUIT DESIGN GOALS:
1/2 THE MASS
4 TIMES THE MOBILITY
100 CYCLES BEFORE REFURBISHMENT
ASSISTED GRIP GLOVES
VACUUM CONNECT / DISCONECT
NASA PHOTO

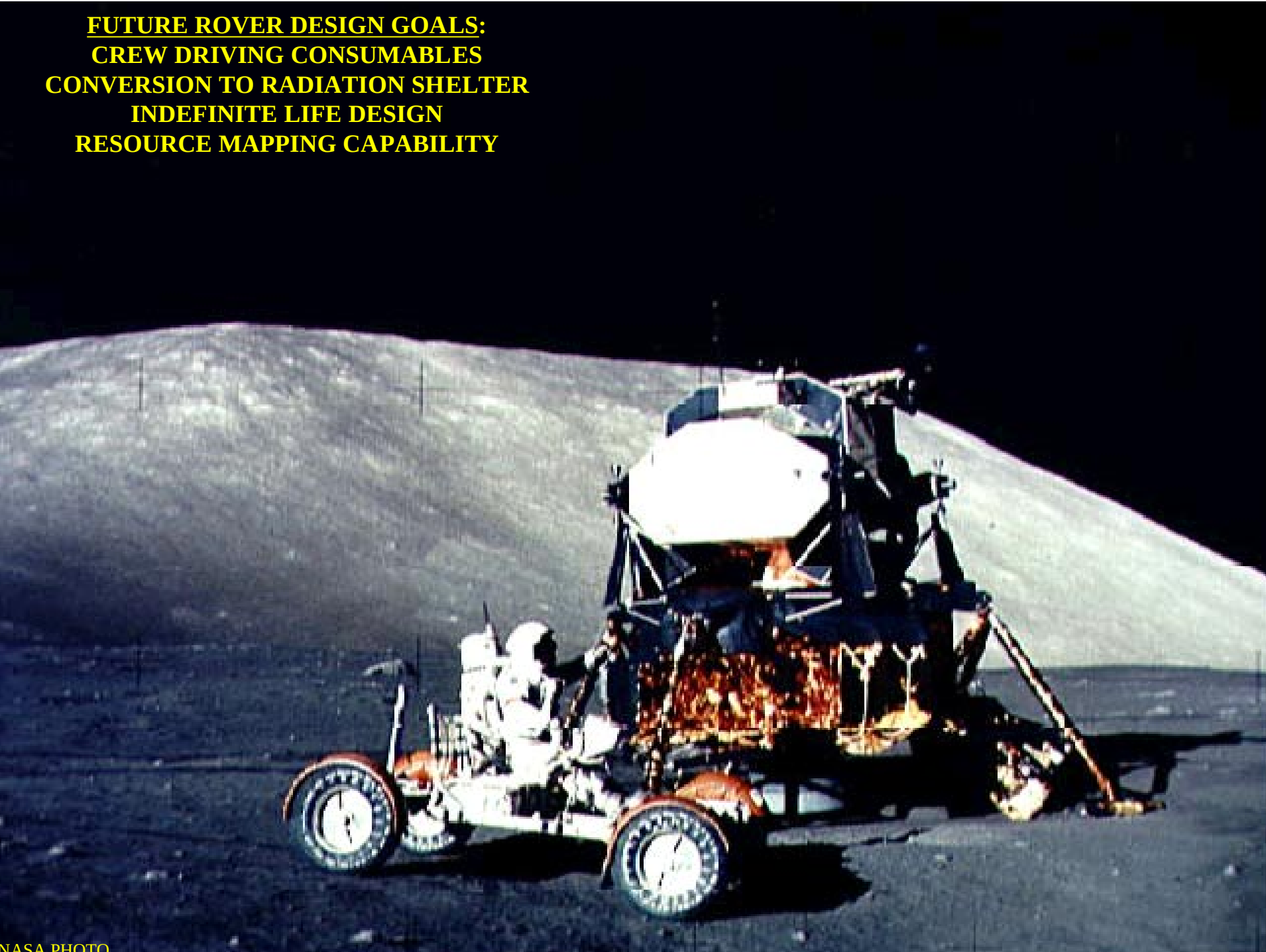
FUTURE ROVER DESIGN GOALS:

CREW DRIVING CONSUMABLES

CONVERSION TO RADIATION SHELTER

INDEFINITE LIFE DESIGN

RESOURCE MAPPING CAPABILITY



NASA PHOTO

RISK AND PRODUCTIVITY MANAGEMENT -3

- **CREW SELECTION**
  - **SKILL MIX AND CROSS-TRAINING**
  - **YOUTH AND TRAINING VS. EXPERIENCE**
  - **PHYSICAL CAPABILITY**
  - **MEDICAL RISK ANALYSIS (?)**
  - **PSYCHOLOGICAL RISK ANALYSIS (?)**
  - **PHYSIOLOGICAL AND PSYCHOLOGICAL TOLERANCE TO SPACE ENVIRONMENT(?)**
    - **SPACE STATION TOUR TO WEED OUT 2%(?)**
  - **COMMITMENT TO LONG TOURS OF DUTY AND / OR SETTLEMENT**
  - **COMMITMENT TO ON SITE HEALTHCARE VS. RETURN TO EARTH**

BASE ARCHITECTURE

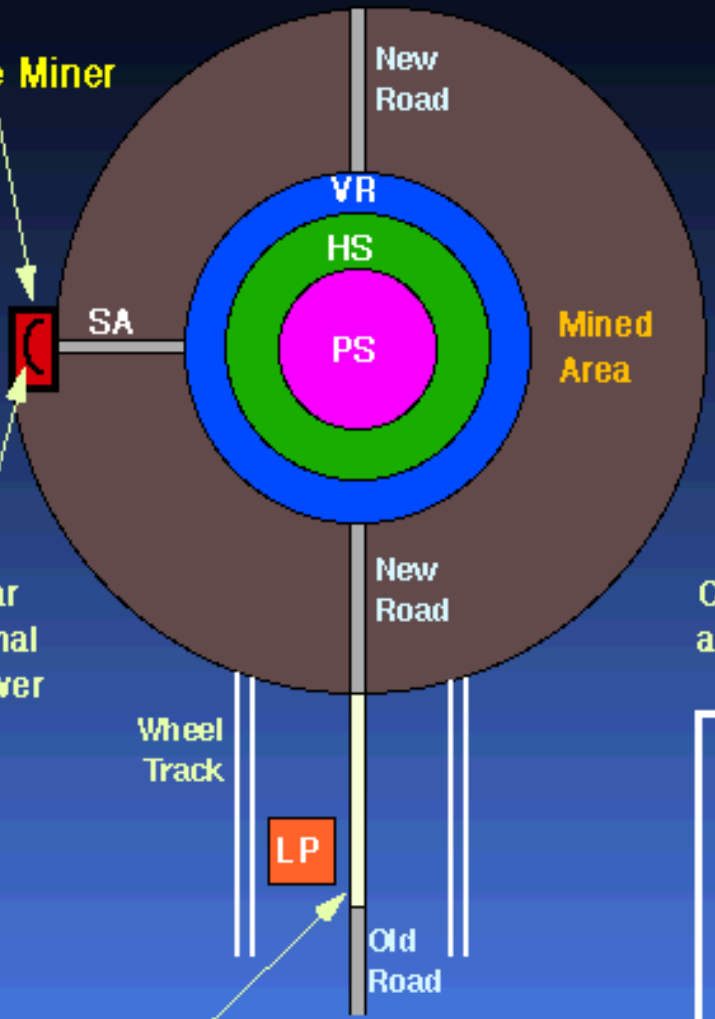
- **GENERAL ARCHITECTURAL LAYOUT OF THE BASE CORE WILL BE FINAL BEFORE THE FIRST LANDING**
  - **SUPPORT INITIAL MINING AND PROCESSING ACTIVITIES**
  - **PROVIDE LONG TERM SUPPORT FOR REGIONAL MINING ACTIVITIES**
- **LANDING AND LAUNCH OPERATIONS WILL BE LOCATED AND DESIGNED SO AS TO NOT DISRUPT OTHER ACTIVITIES**
  - **DUST CONTROL**
- **LANDERS AND RESOURCE TRANSFER MODULES WILL BE ACCESSIBLE TO REFUELING AND RESOURCE TRANSFER FACILITIES**
  - **LAND TO BEACONS**
- **ROADS AND WALKWAYS WILL BE STABILIZEDFOR DUST CONTROL**
- **CRATERS RESERVED FOR CRYOGENIC STORAGE OF BY-PRODUCTS**

WISONSIN MARK 4 MINER CONCEPT
RECTILINEAR MINING MODE

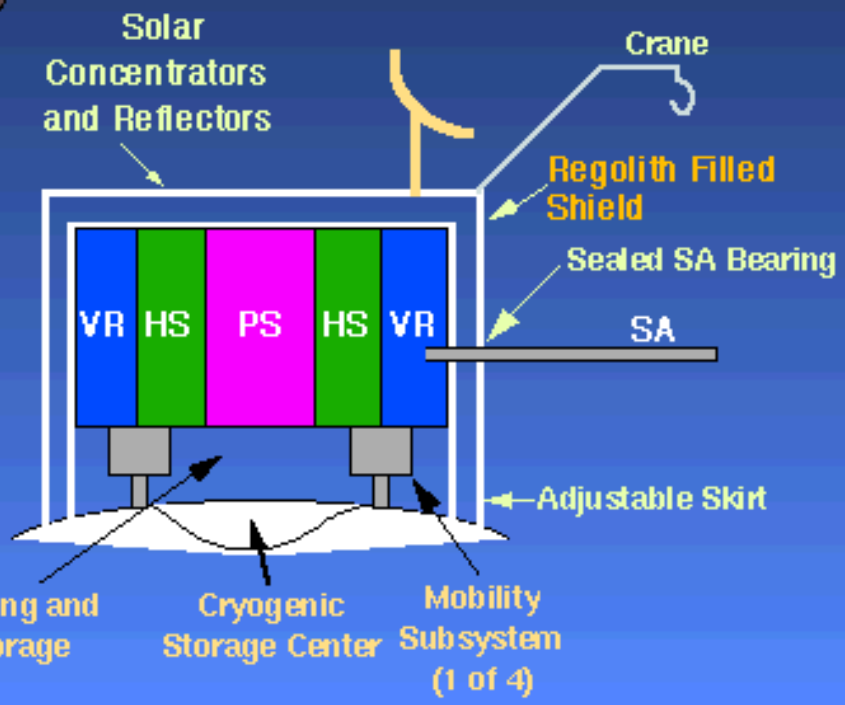
Spiral Mining System for Lunar Volatiles

Mobile Miner

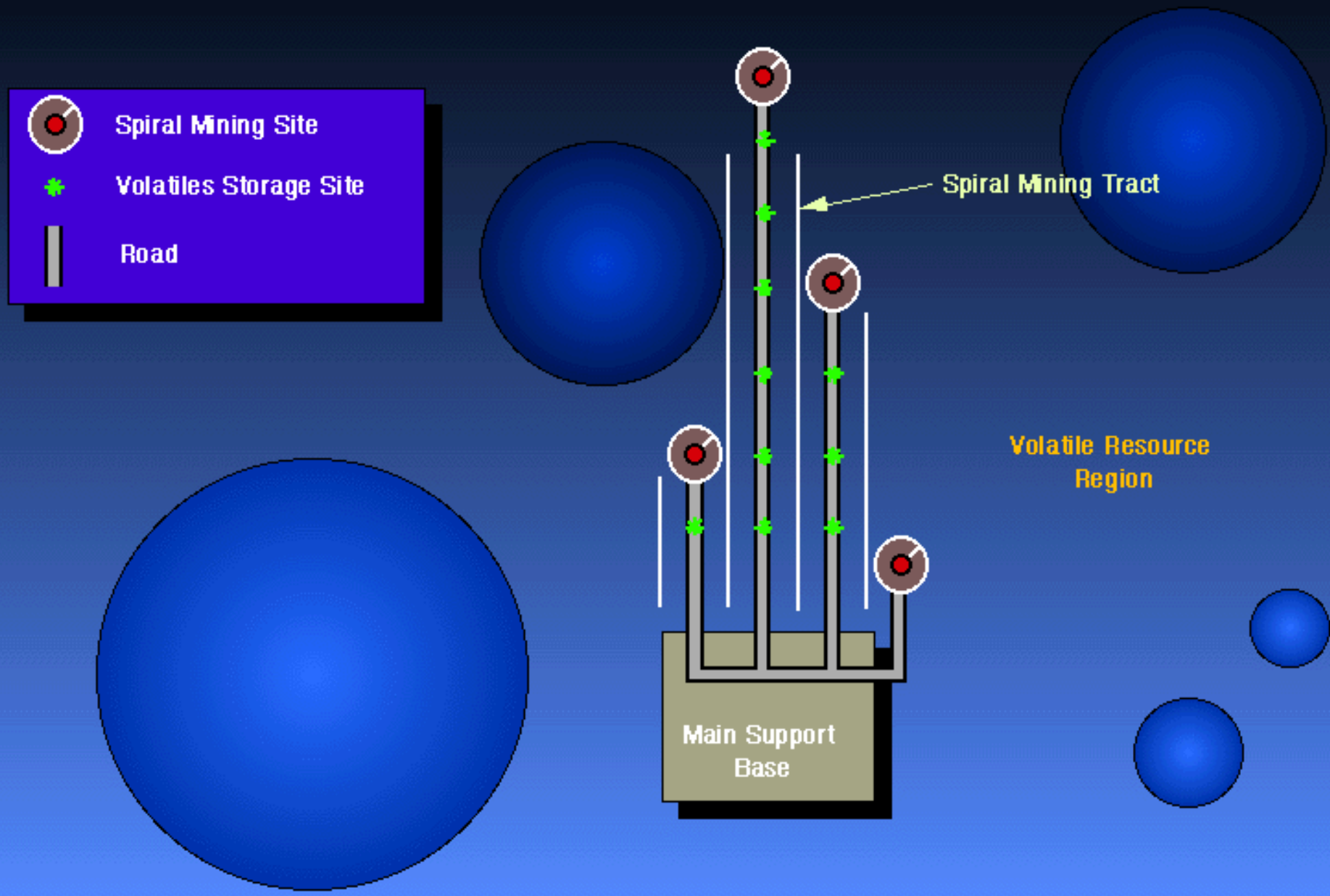
Solar Thermal Receiver



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



Regional Mining Plan Utilizing Spiral Mining Systems



PRE-ACTIVATION REQUIREMENTS

- **SET LUNAR BASE DESIGN GOALS**
  - **INDEFINITE SUPPORT OF HUMAN ACTIVITIES**
  - **NEAR TERM OXYGEN AND HYDROGEN PRODUCTION**
  - **LONG TERM ^{3}HE PRODUCTION**
  - **LONG TERM PRODUCTION OF BASIC MATERIAL AND FOOD REQUIREMENTS**
  - **ANCILLARY USE OF THE MOON**
- **ASSUMED FREQUENCY OF LAUNCHES OF MAJOR SUPPORT MISSIONS TO THE MOON**
  - **ONE PER LUNAR CYCLE**
- **ENGINEERING DESIGNS**
  - **DESIGN FOR INDEFINITE LIFE THROUGH ANTICIPATORY MAINTENANCE**
  - **FINALIZED PRIOR TO INITIATION OF BASE ACTIVATION**
- **SITE OF FIRST BASE**
  - **BEST LOCATION FOR INITIAL ^{3}HE PRODUCTION**
  - **H_2, H_2O AND O_2 PRODUCTION CAN OCCUR FROM REGOLITH AT ANY LOCATION**

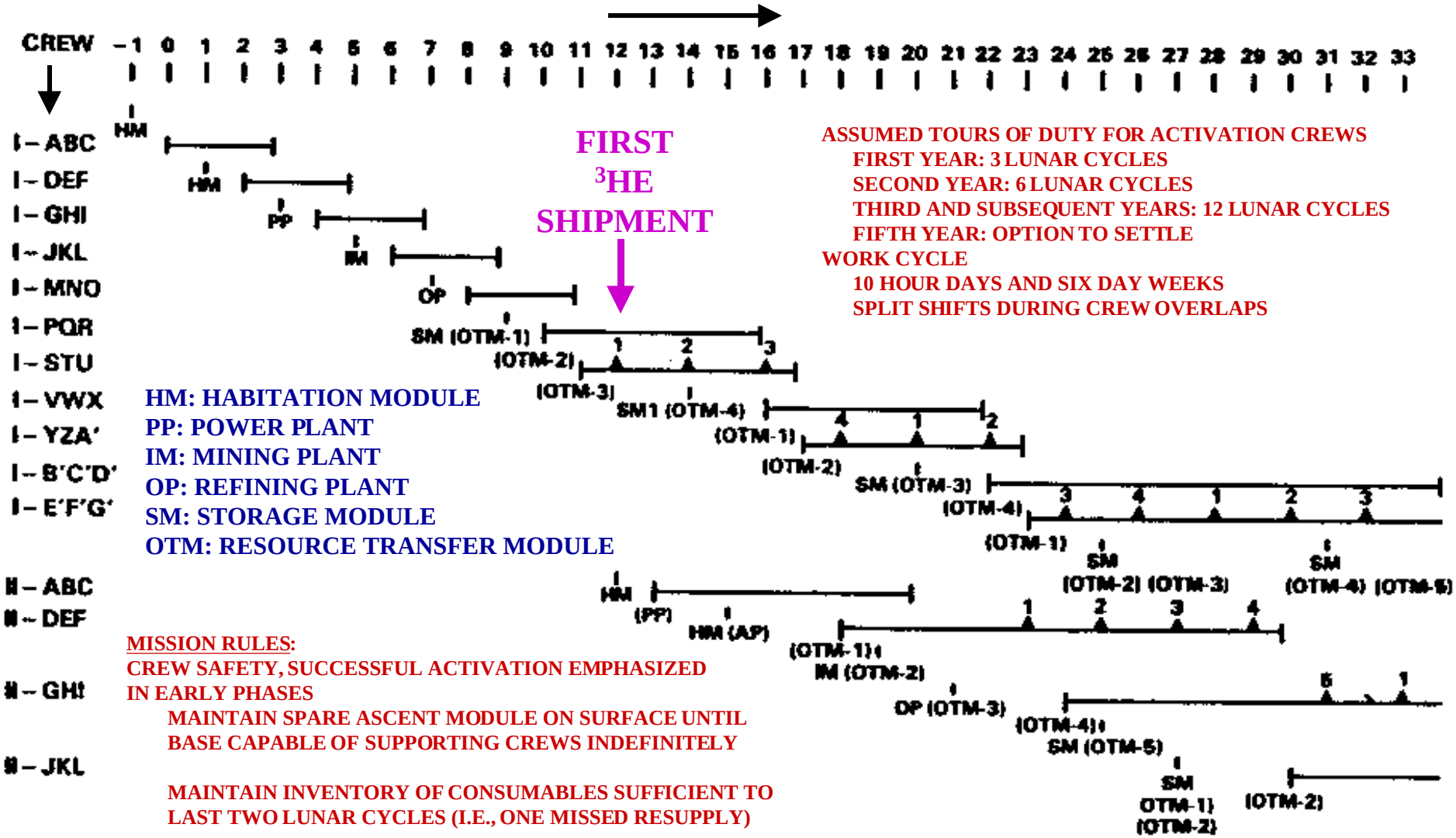
OPERATIONAL SUPPORT

- **POWER PRODUCTION**
  - **EARLY PHASES: SOLAR ENERGY / BATTERY / RTG / FUEL CELL**
  - **MID PHASES (O2 AND H2 PRODUCTION): SOLAR ENERGY / FUEL CELL**
  - **LATE PHASES AND SETTLEMENT: NUCLEAR FISSION OR FUSION**
    - **SOLAR ENERGY AND FUEL CELLS FOR SPECIAL PURPOSES**

- **HUMAN CONSUMABLES**
  - **AS EARLY AS FEASIBLE: PHASE-IN LUNAR PRODUCTION UNTIL INDEFINITE SUPPORT POSSIBLE FROM LUNAR RESOURCES**

- **REAL-TIME OPERATIONAL 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**
  - **LAUNCH: EARTH-BASED**
  - **TRANS-LUNAR AND TRANS-EARTH: MOON-BASED**
  - **BASE AND MINING ACTIVITIES: MOON-BASED**
  - **HEALTHCARE: EARTH-BASED WITH EARLY TRANSITION TO MOON**

SUMMARY TIMELINE
(LUNAR CYCLES FROM FIRST CREW LANDING)



FIRST ^{3}HE SHIPMENT

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

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

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)

COST-TRADE STUDIES

- **HELIUM-3 FUSION BUS BAR COSTS VS. COMPETITION (CONTINUING)**

- **MINE PLANNING / FACILITY DESIGN WITH EXISTING DATA BASE VS. OBTAINING MORE DATA**

- **LAUNCH RATES VS. CREW STAY TIME / SIZE DURING ACTIVATION**

- **ESTIMATED COST / TONNE COMPARING MINING STATEGIES**
- **PERCENTAGE MINABLE LEFT UNMINED VS. MARGINAL COSTS TO MINE**
- **USE OF SUPPLEMENTAL EQUIPMENT, E.G., BULLDOZERS TO CLEAR BOULDER FIELDS.**
- **BALANCE BETWEEN EXTRACTION AND REFINING AND SHIPMENT AND STORAGE**
- **ROBOTIC VS. TELE-ROBOTIC VS. CREW ASSISTED OPERATIONS**
- **STORAGE VS. THROW-AWAY WITH RESPECT TO BY-PRODUCTS**

- **LOGISTICAL SUPPORT COSTS: IMPORT VS. RAPID DEVELOPMENT OF LUNAR RESOURCES**

AGRICULTURAL RESEARCH

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

- **HABITAT AND INDOOR WORKING FACILITIES PERSONNEL FRIENDLY**
  - **ELECTONIC, REALTIME WINDOWS**
  - **PIPED IN NATURAL LIGHT**
  - **PRIVACY AREAS**
  - **PERSONAL GARDEN PLOTS**
  - **INDIVIDUAL AND PRIVATE VOICE AND ELECTONIC COMMUNICATIONS BACK TO EARTH**

- **PLAN ON EXTERIOR RECREATION**
  - **ADDITIONAL DEMAND ON SPACE SUIT LONGEVITY AND RELIABILITY**

- **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 TO BASIS FOR 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**