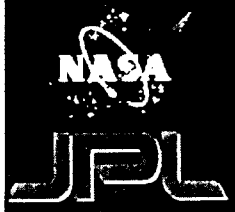
space exploration NASA theme



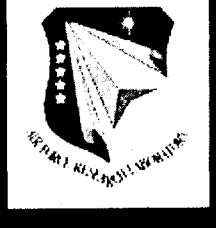

California Institute
of Technology

# NASA Space Exploration

## "A View To the Future"

**Michael Sander**

**Space Power Workshop 1999**



**Air Force Research Laboratory**

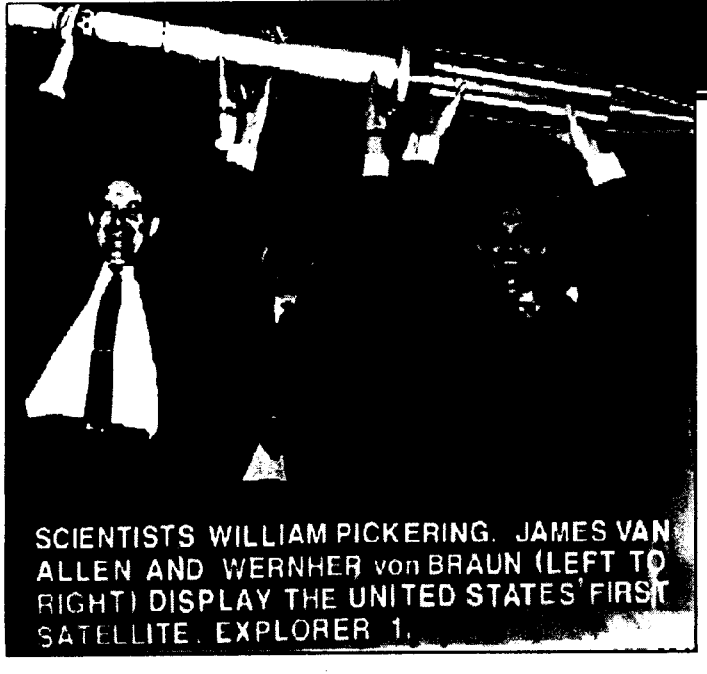
**April 20, 1999**

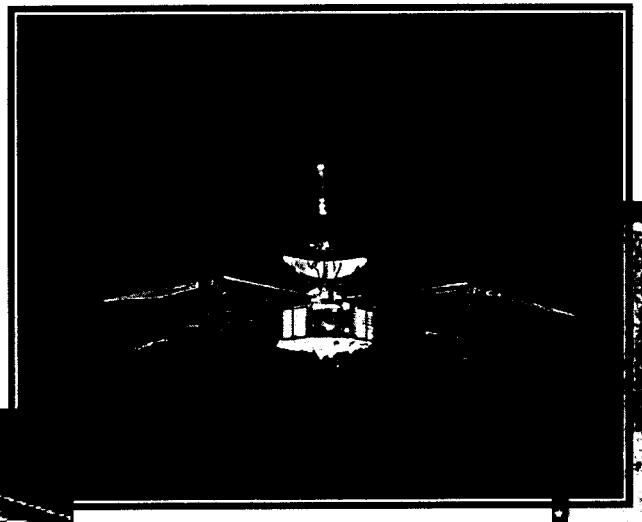
# A Core NASA Theme

## *Life – Where and How?*

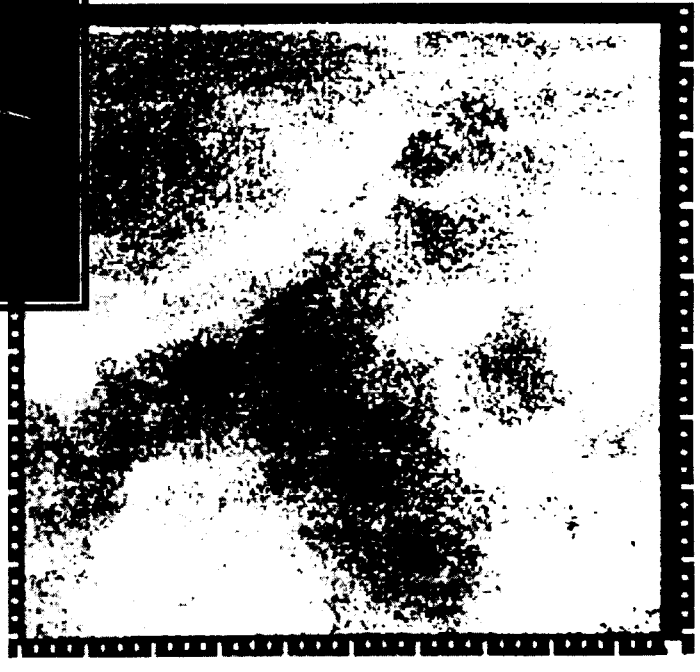
# The First Era: Getting There
# 1958-1995

**Explorer**
**"America's First"**
**1958**



**Mariner 4 to Mars**
**1964**

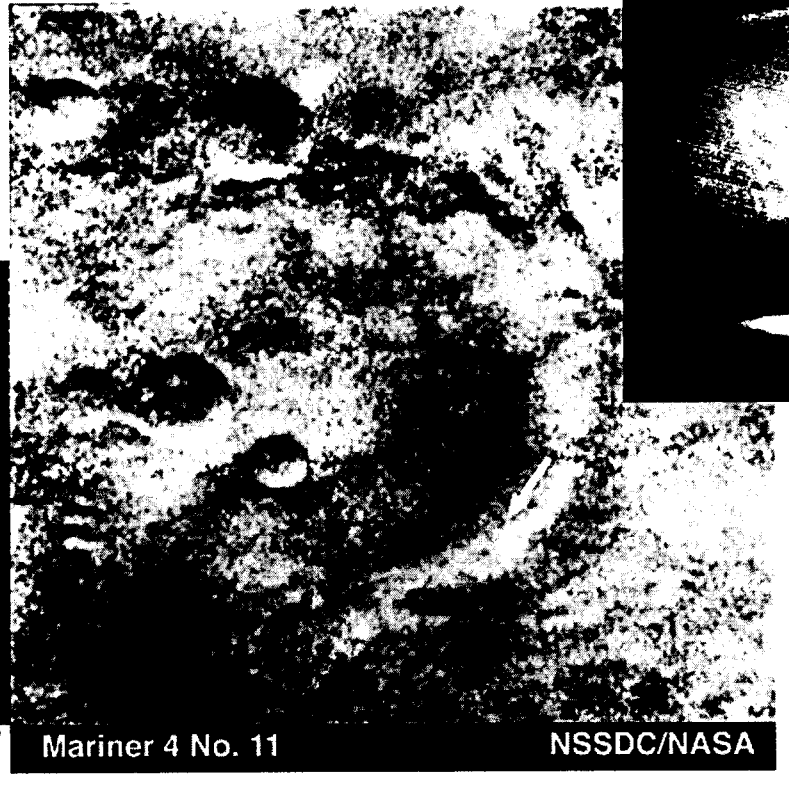


**Mariner 4 View of Crater Rims -**
**Southern Highlands of Mars**

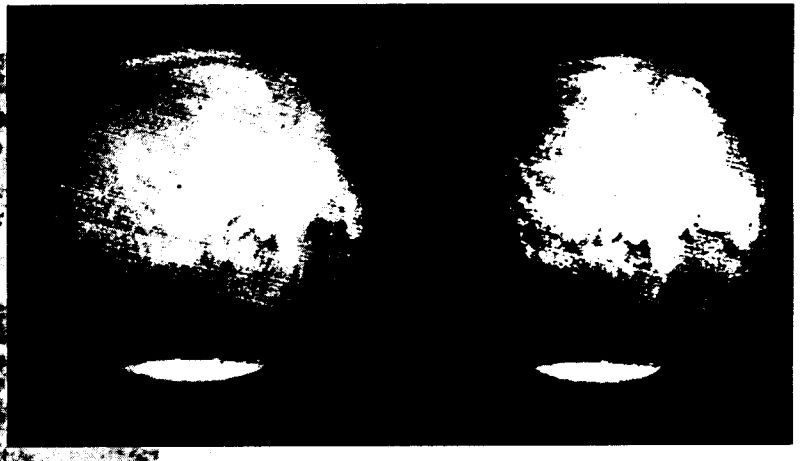
# Mars Exploration-A Case Study

Drawing of Mars by
E. M. Antoniadi, 1909

"the drab and moonlike Mars "



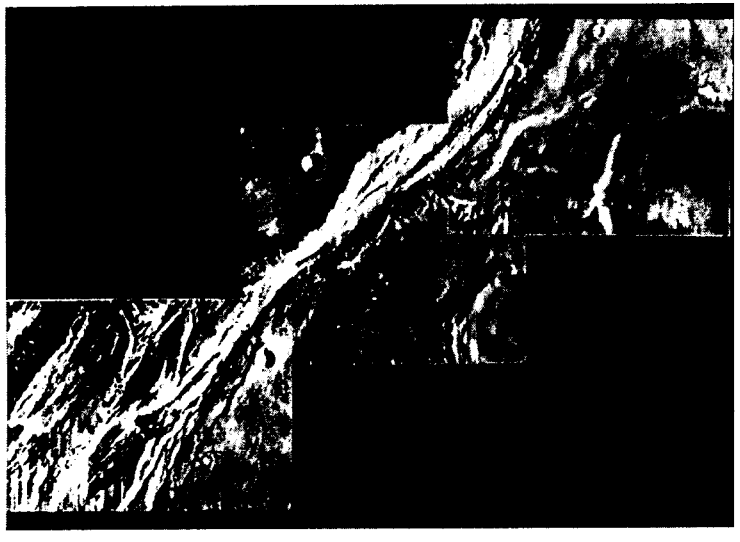

**Mariner 4**
**"1st glimpse of Mars" 1964**



**Mariner 7**
**1969-70**

# Mars Exploration-A Case Study

**Mariner 9-"1st Spacecraft to orbit another planet" 1971-72**



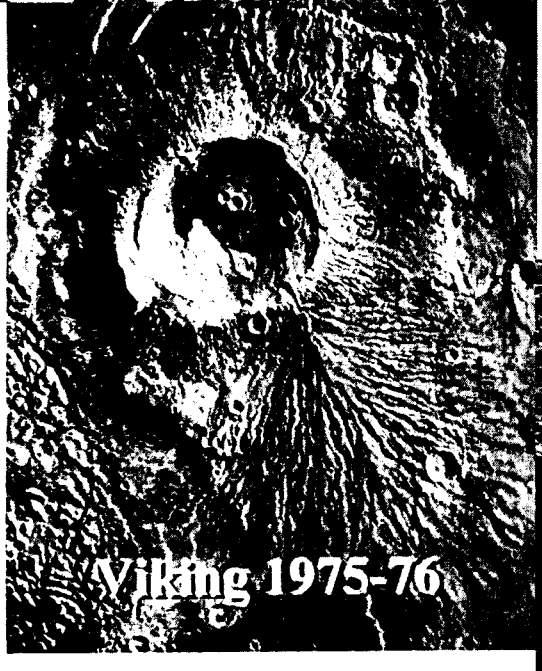
Mariner 9 found networks of channels and tributaries that appeared to be runoff channels and dry riverbeds

Neither Earth nor another Moon; it was Mars---"itself alone."

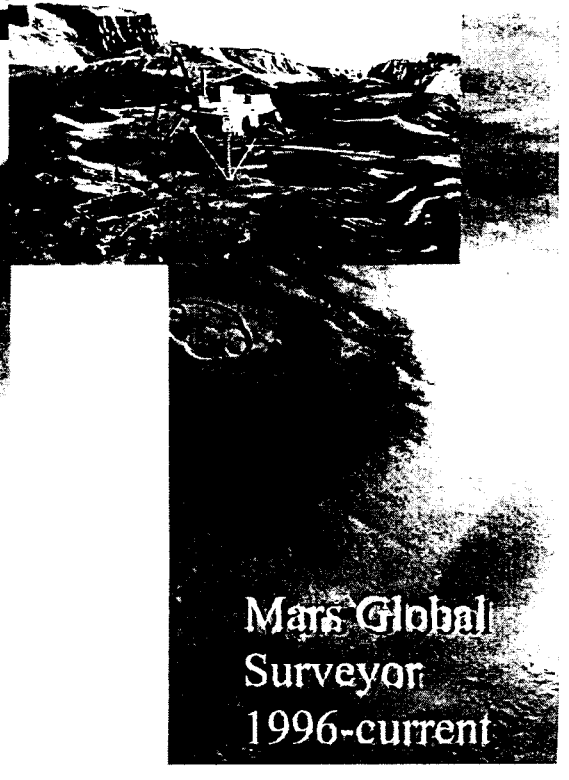
# Mars Exploration-A Case Study

**Mars has a very complex history... with many open questions**

Mars '01

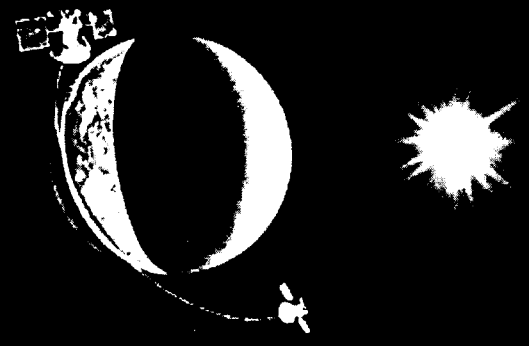


Mars Lander '98 (MVACS)

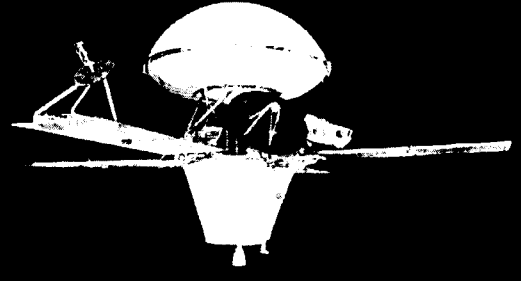


# The Second Era: Finding Out What's There
# 1975-1995

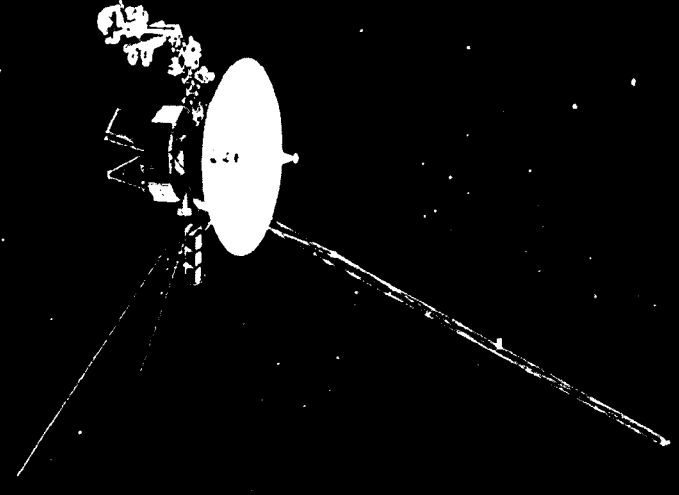
## Magellan to Venus



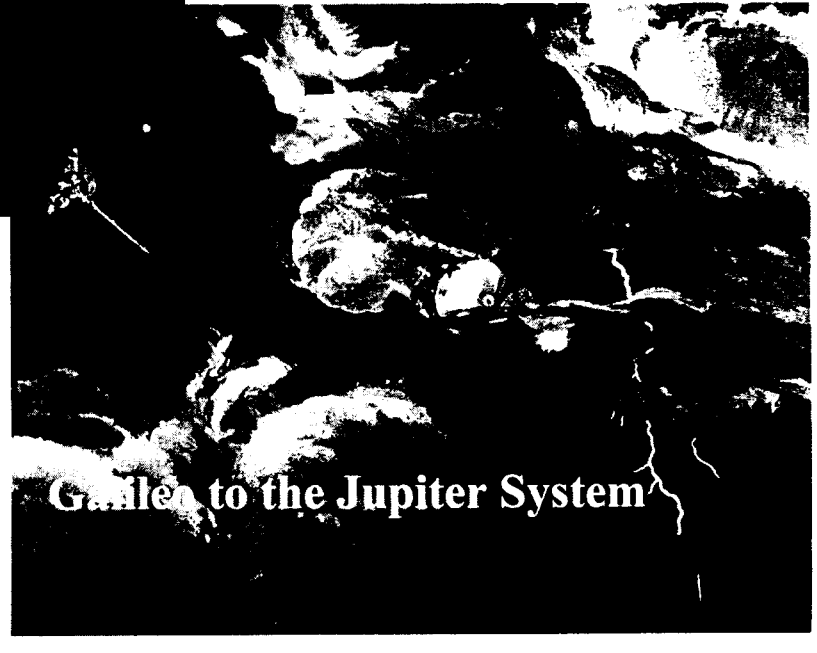
## Cassini to the Saturnian System



## Voyager to the Solar System

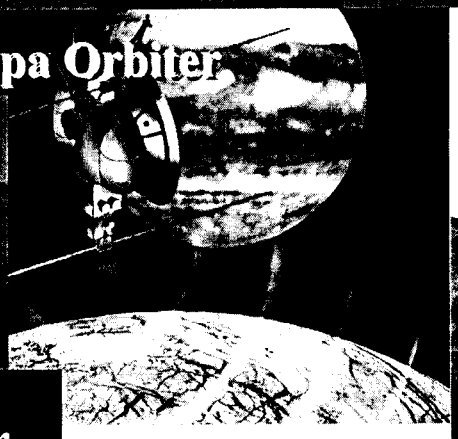


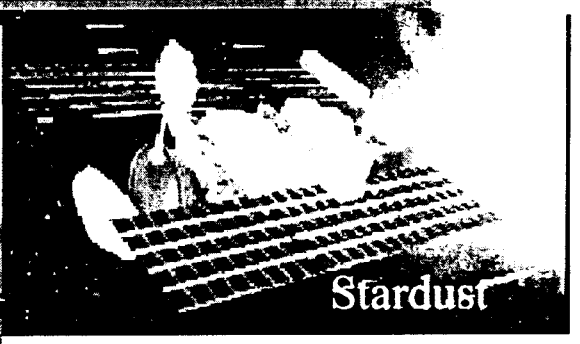
## Viking to Mars

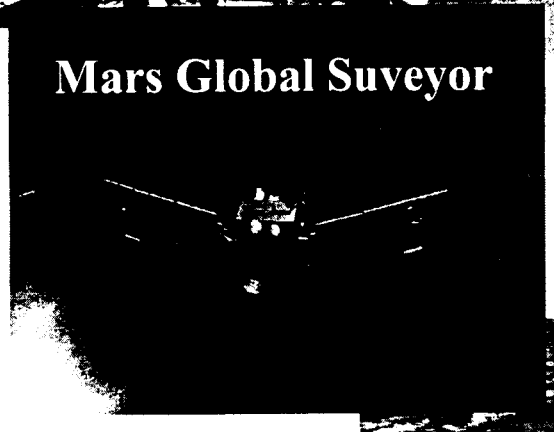


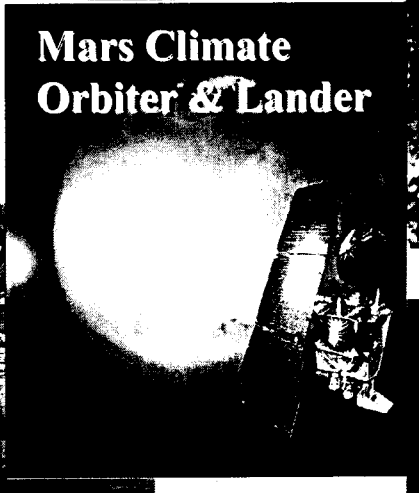
## Galileo to the Jupiter System

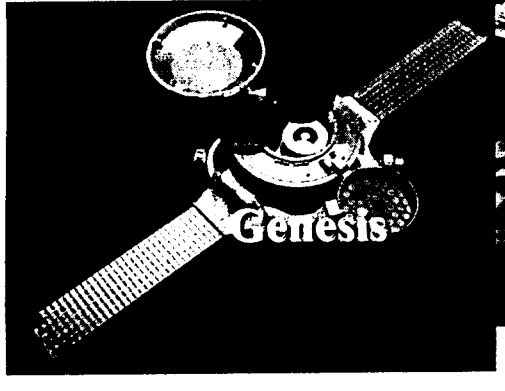
# The Third Era: Getting There Often and Getting Back: 1995-2005+

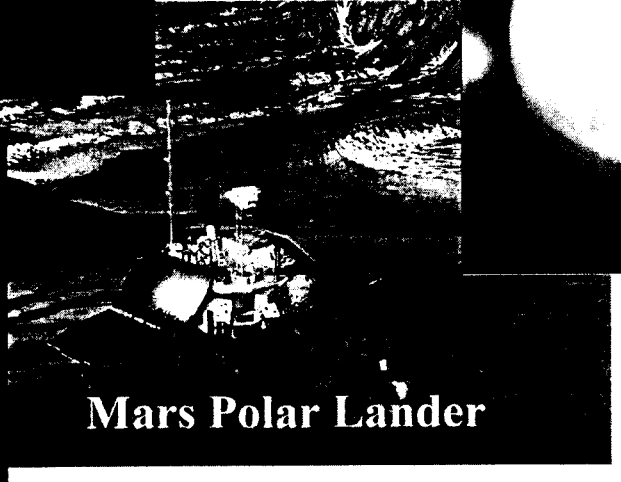


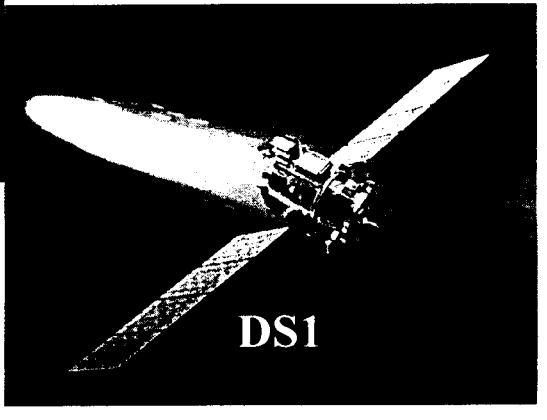




# HISTORY OF EXPLORATION AND DEVELOPMENT OF WESTERN U.S.

1800 1825 1850 1875 1900

**EXPLORATION**

Spanish

1804-1806 Mapping Lewis and Clark

1868-1874 Remote Regions John Muir

1885 Stanford University Founded

**INFRASTRUCTURE**

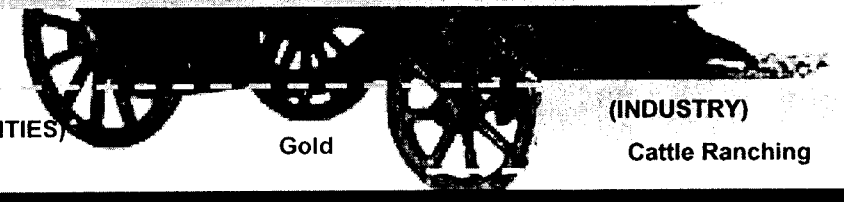
1840 Oregon Trail used for migration west

Morse code used to telegraph

1869 First Transcontinental Railroad

1876 Telephone invented

Commercial electricity available



**COMMERCE**

(RARE COMMODITIES) Furs

Gold

(INDUSTRY) Cattle Ranching

Agriculture

# FUTURE OF EXPLORATION AND DEVELOPMENT OF DEEP SPACE

2000 2005 2015 2030 2057

**EXPLORATION**

1st Era

Comet Sample Return

Mars Sample Return Missions Samples From Venus

End 1st era Pluto, Kuiper

Mars Robotic Outposts

First Humans to ?

Europa Oceans Explored

Human Outposts on Mars

First Interstellar Mission

Permanent Robotic presence throughout Solar System; "Self-Aware" Flight Systems Human Settlements on Mars; Mars exploration conducted from Mars

**INFRASTRUCTURE**

Mars Comm/Nav Network in place

Comm/Nav Network begun at Mars

Optical Comm Capability Demonstrated

Optical Comm Relays and GPS for Inner Planets

Solar System Internet for Inner Planets

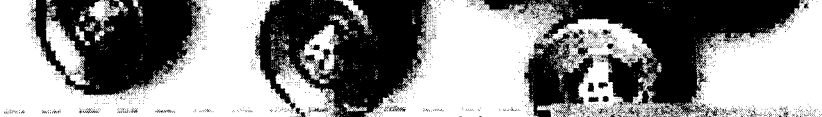
Optical Comm Relays and GPS for Outer Planets

Solar System Internet for Outer Planets

Mars Internet commercialized; first commercial deep space tracking facility

Infrastructure for Mars activities exists on Mars

Solar System-wide GPS & Internet



**COMMERCE**

(RARE COMMODITIES)

First Commercial Asteroid Mission

First Commercial Exploitation Missions

Breakthrough discovery of profitable deep space use

(INDUSTRY)

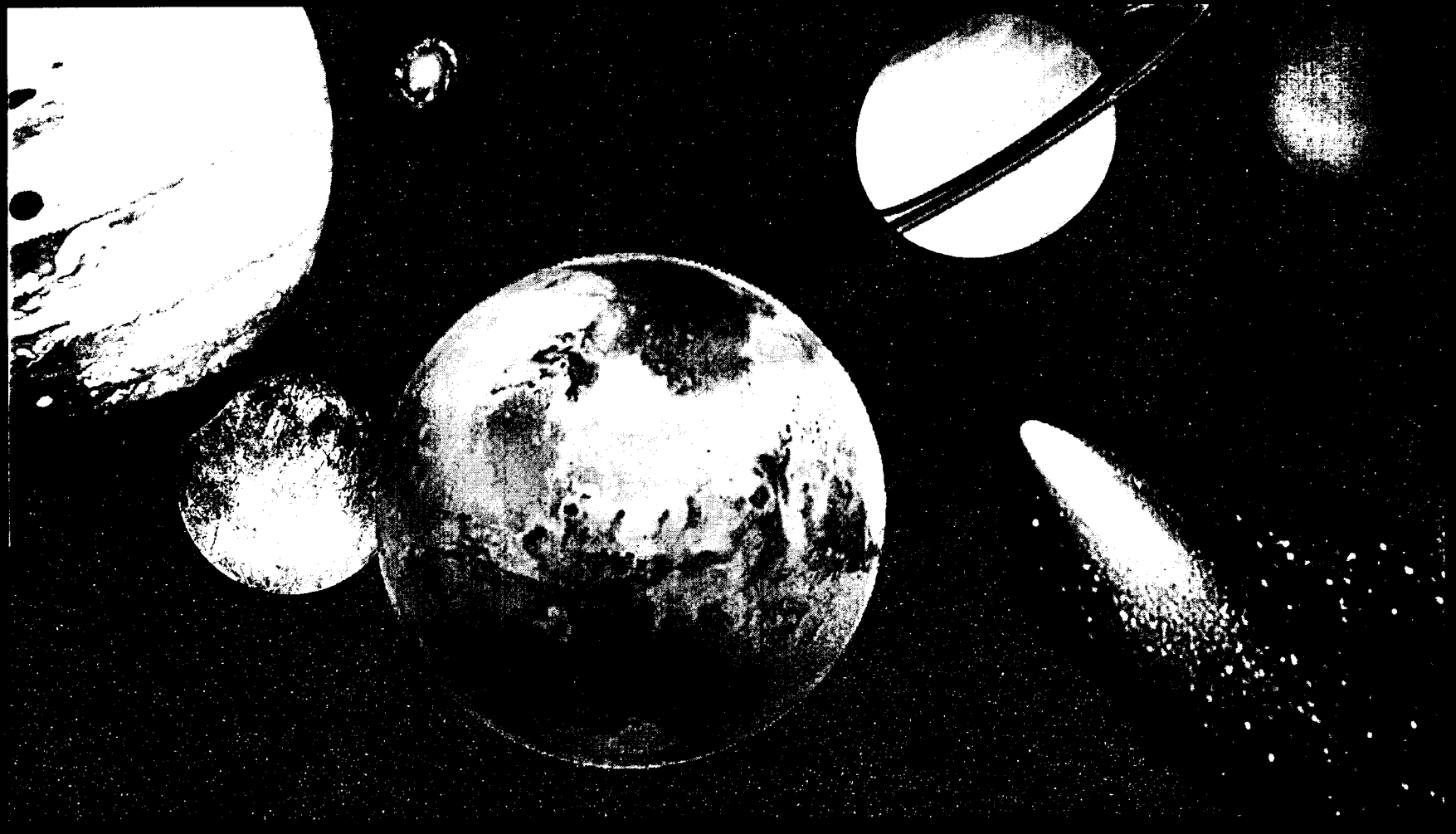
First Fully Profitable Deep Space Venture

Humans on Mars engaged in Commerce as well as Exploration

Asteroid and Mars/ Moon Mining

Courtesy Ann Tavormina

# Life In the "Immediate Neighborhood" ?



# Mission Approaches

## Europa

**Radar Sounder**
**Lander**
**Ice Penetrator**

## Mars

| | |
|---|---|
| **Sample Return** | **2003, 2005…** |
| **Micro Missions** | **2001...** |
| **Polar Landers** | **1999** |
| **Climate Orbiter** | **1999** |
| **Surveyor** | **1997** |
| **Pathfinder** | **1997** |

## Interesting Challenges

**Affordable Transportation**
- Getting into Orbit
- Getting to the Surface
- Getting Through the Ice

**Radiation**
- 4 Mega Rads in 30 Days

**Communications**
- Through the Ice

**Autonomy**
**Power**
**Compact Instrumentation**

**Sample Handling**
**Bioload Reduction**
**Costs of Transportation**
**Communication Infrastructure**
**Precision Rendezvous**
- On the Surface
- In Orbit

**Autonomy**
**Mobility**

# Mission Approaches

## Sample Return Missions From:

- Comets
- Venus
- Other Solar System
- Other Objects

## Robotic Outposts

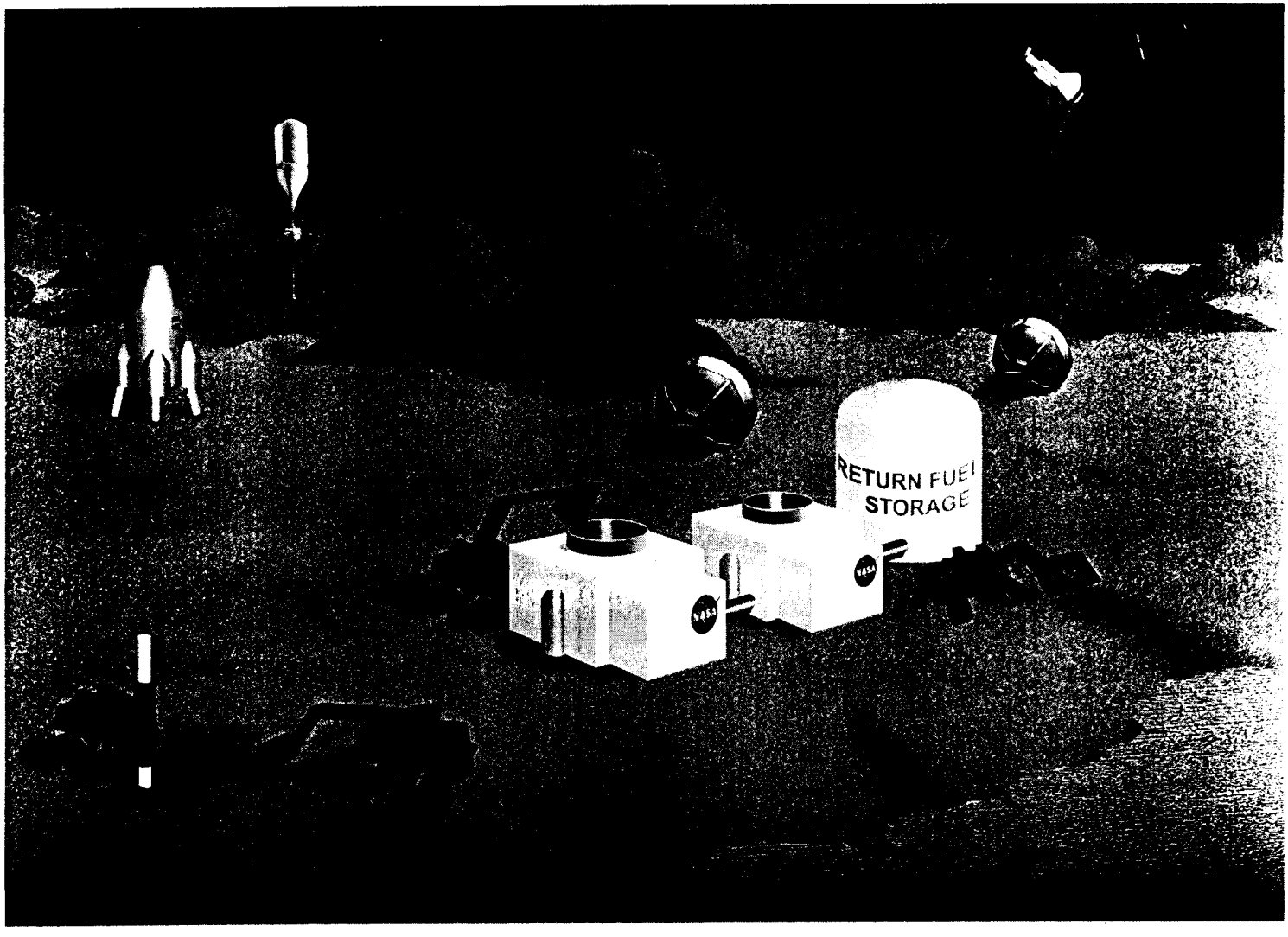
- Mars
- Moon
- Others

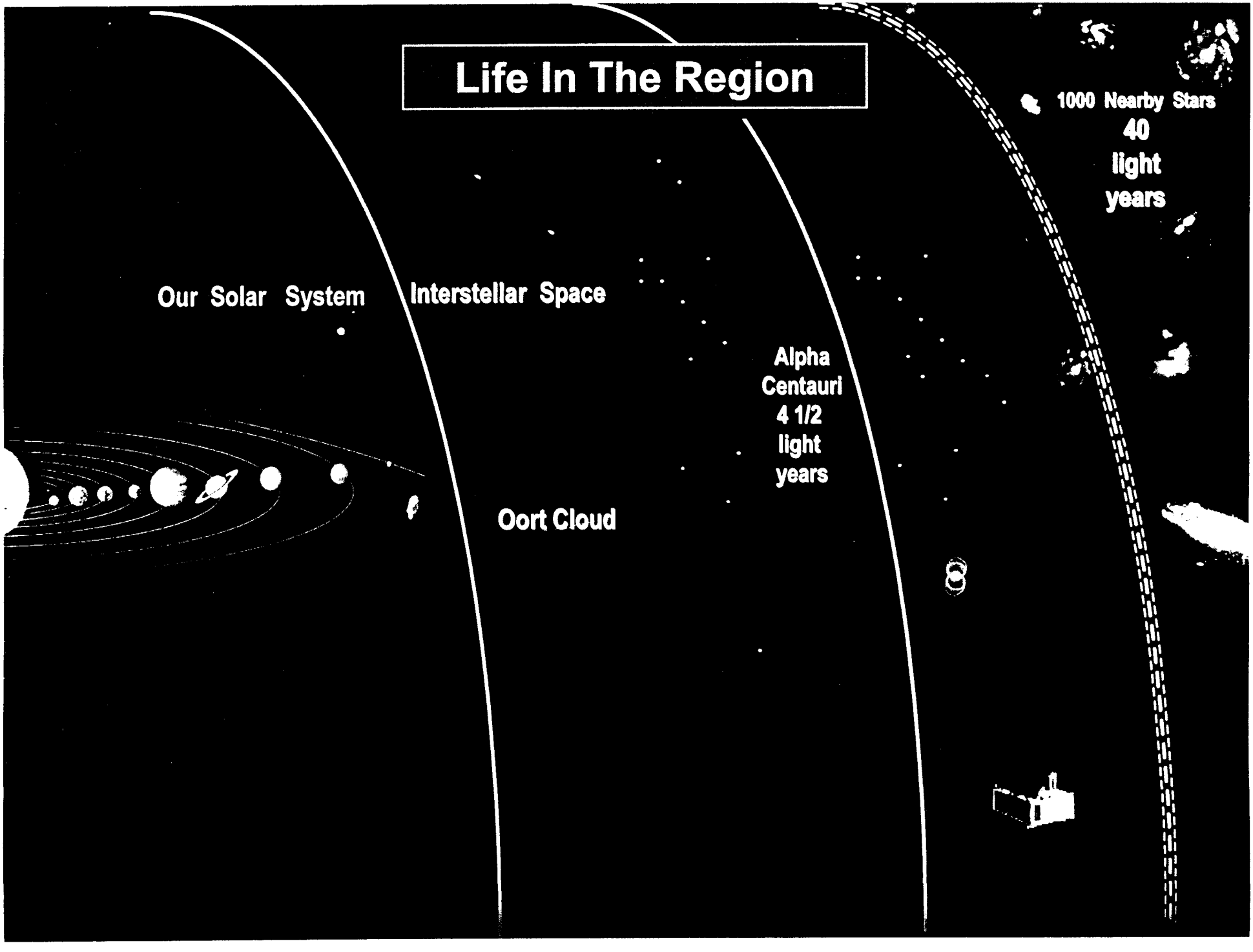
## Interesting Challenges

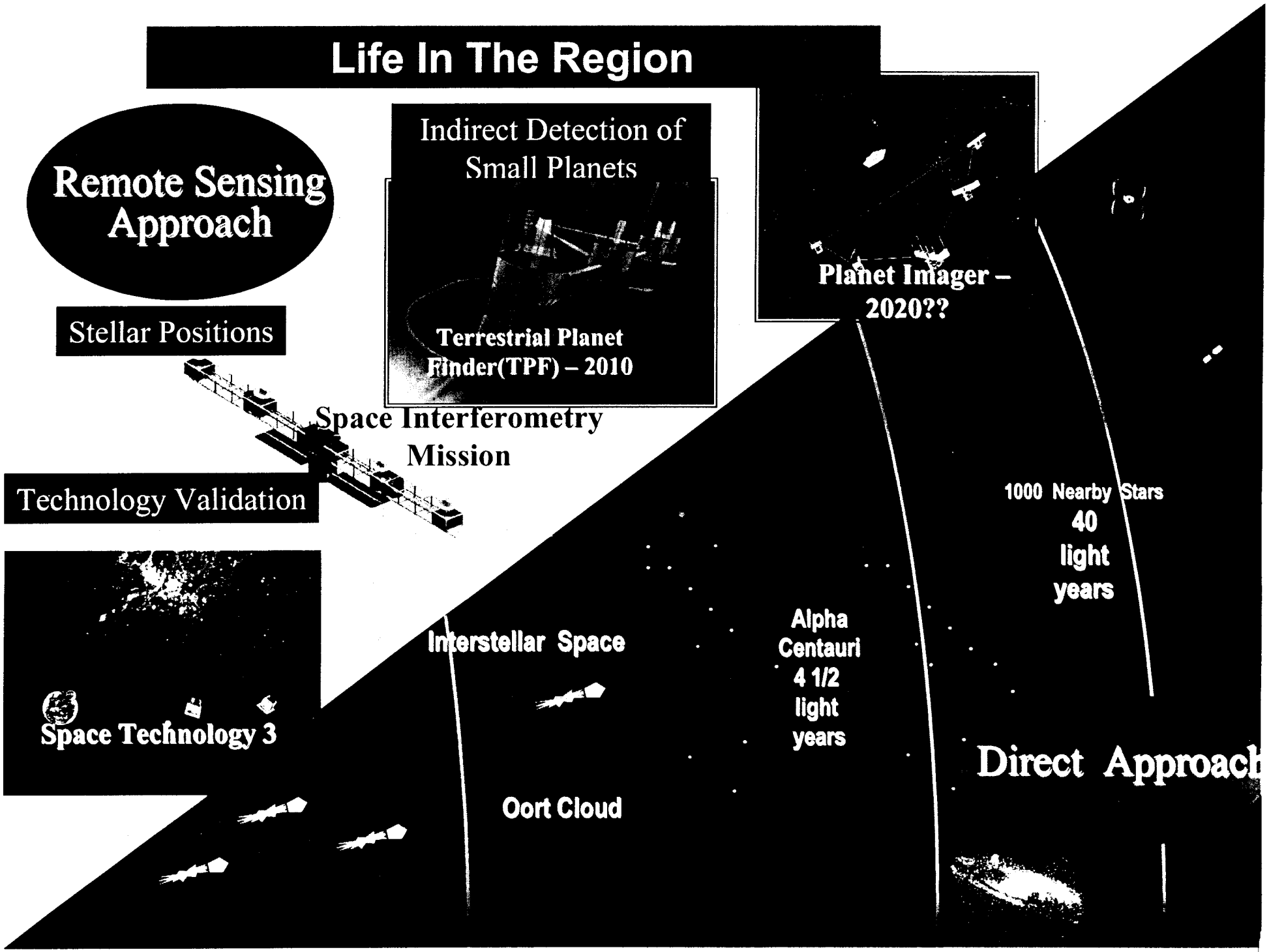
- Simple Sample Acquisition Handling and Return
- Operation in Extreme Environments
- Cost of Transportation
- Bio Load Reduction

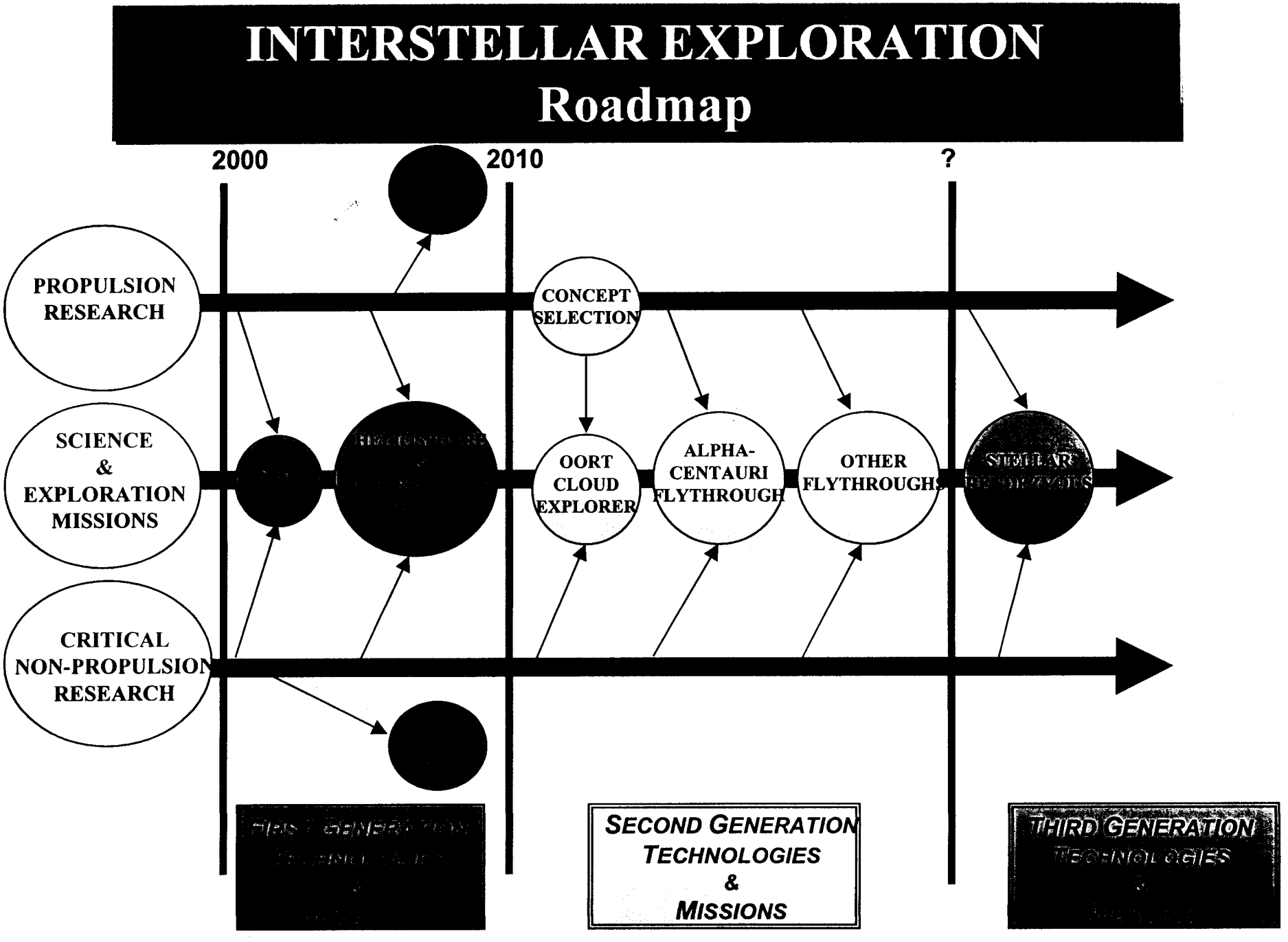
- In Situ Logistics
- Low Cost Transportation
- Mobility
- Precision Rendevous
- Communication
- Autonomy
- Micro-laboratories

# Robotic Outpost

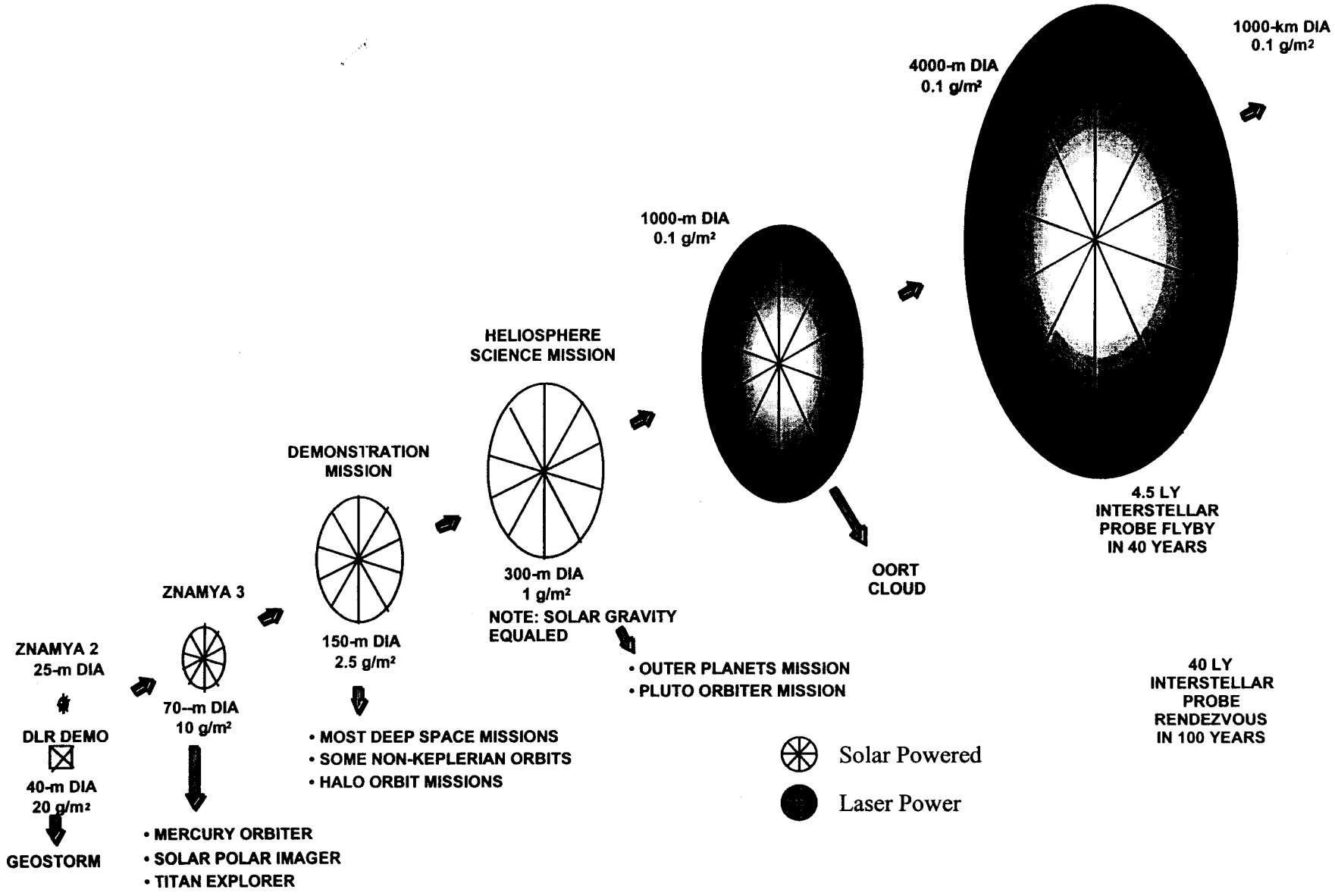



Life In The Region
1000 Nearby Stars
40
light
years
Our Solar System
Interstellar Space
Alpha
Centauri
4 1/2
light
years
Oort Cloud

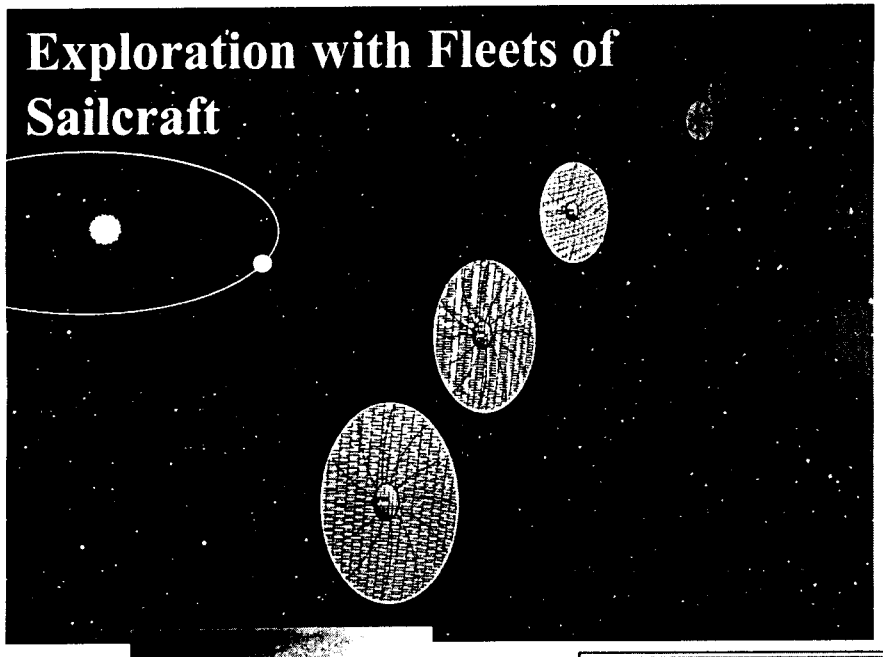

Life In The Region
Remote Sensing Approach
Indirect Detection of Small Planets
Terrestrial Planet Finder(TPF) – 2010
Planet Imager – 2020??
Stellar Positions
Space Interferometry Mission
Technology Validation
Space Technology 3
1000 Nearby Stars
40 light years
Interstellar Space
Alpha Centauri 4 1/2 light years
Direct Approach
Oort Cloud

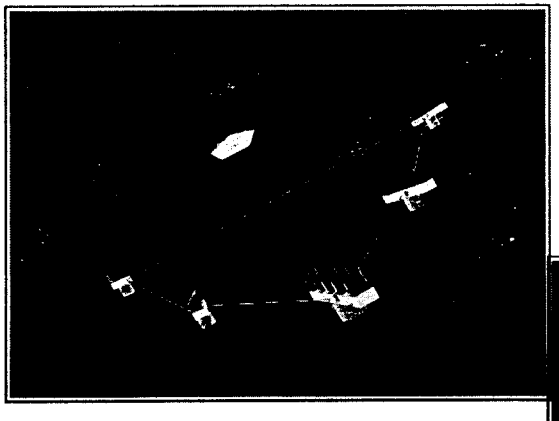

INTERSTELLAR EXPLORATION
Roadmap
2000
2010
?
PROPULSION RESEARCH
SCIENCE & EXPLORATION MISSIONS
CRITICAL NON-PROPULSION RESEARCH
CONCEPT SELECTION
OORT CLOUD EXPLORER
ALPHA-CENTAURI FLYTHROUGH
OTHER FLYTHROUGHS
SECOND GENERATION TECHNOLOGIES & MISSIONS
THIRD GENERATION

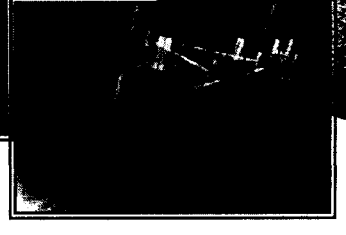
# INTERSTELLAR EXPLORATION
## Sail Roadmap

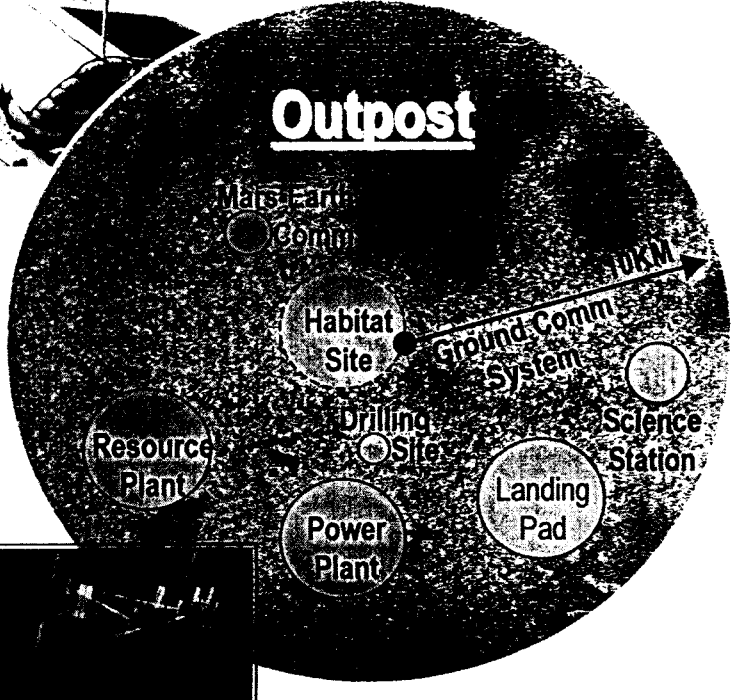


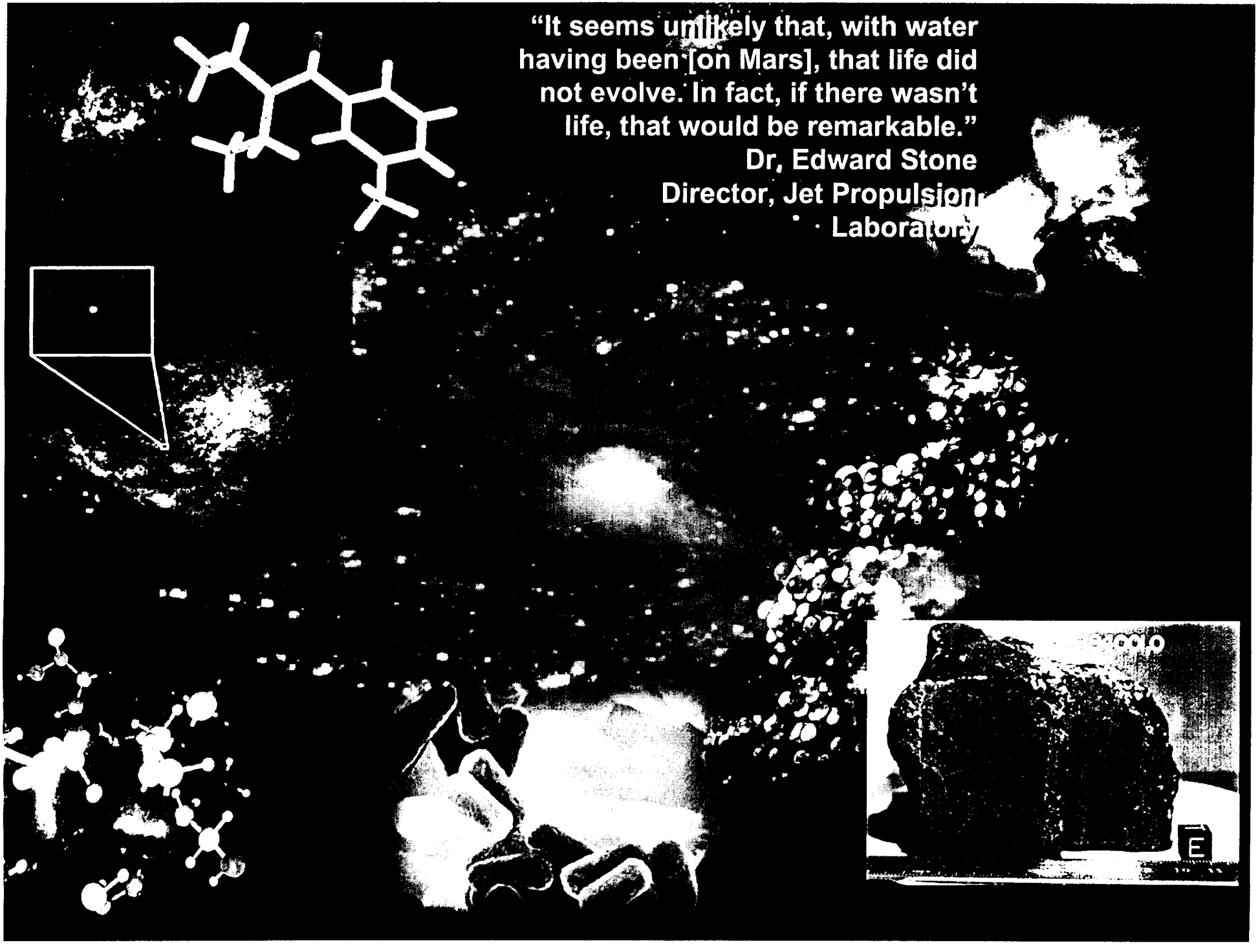
# Fourth Era: 2005-2020?
# Permanent Robotic Presence and Outward Bound










"It seems unlikely that, with water having been [on Mars], that life did not evolve. In fact, if there wasn't life, that would be remarkable."
Dr, Edward Stone
Director, Jet Propulsion Laboratory