Instrument Technologies for the Detection of Extraterrestrial Interstellar Robotic Probes

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Extraterrestrial Intelligence Issues

- **A CHALLENGING SET OF QUESTIONS**
  - **Does ETI exist in the Galaxy?**
    - What forms? AI, Organic, Cybernetic, other?
  - **How old are ETI civilisations?**
    - Presumed ancient, the older the better (large L)
  - **How far away is ETI from Earth?**
    - Within < 500 LY radius would be very fortunate
  - **How advanced is ETI technologically?**
    - Presumed to be >> 1000 years beyond Earth technology
  - **What are the manifestations of ETI Technology?**
    - Laser Pulses, Radio Beacons, Robotic Probes, Energy Emissions, other?
  - **How do we search for ETI?**
    - Optical Telescope, Radio Telescope, Sensor Platforms, other?
  - **Should our civilization be searching for ETI?**
    - The scientific debate continues, opinion polls say ***YES*!**

Technological Manifestations of ETI

- **TWO MAIN TYPES OF MANIFESTATIONS**
  - **Energy Markers and Matter Markers**
- Electromagnetic Energy Markers
  - Narrow Band Beacons (λ = 18 & 21 cm) [Cocconi and Morrison]
  - RF Beacons (pulsed or CW) in the 1-60 GHz microwave window
  - RF Surveillance, Radar or Telecommunications leakage
  - Pulsed Laser Beacons ($0.5 < \lambda < 1$ μm) [Oliver, Ross, et al]
  - CW Laser Optical Communications ($0.5 < \lambda < 10$ μm) [Schwartz & Townes]
  - Hyperfine Line Emissions (λ = 1.5 mm) [Kardashev, Steffes]
  - Artificial emission lines (Fraunhofer, Balmer and Lyman series) [Ross, et al]
  - Stellar dumping to alter solar emission spectra [Drake, Sagan, Shklovski]
  - Super Nova X-ray Echoes [McLaughlin]
  - Gamma Bursts from Propulsion Systems [Freitas, Zubrin]

Technological Manifestations of ETI

- **Matter Markers – Robotic Probes and Artifacts**
  - * Relativistic or Fast Flyby's [Maccone, et al]
  - * Ancient Artifacts
    - "Drift-Through's" swept up by the solar systems galactic orbit
  - * Asteroid Belt Artifacts [Pappagainnis]
  - * Heliocentric Orbits
    - Elliptical or Earth-Crossing
  - * Self-Reproducing Automata (aka Von Nuemann probes) [Boyce, et al]
  - * Libration Points
    - Earth-Moon-Sun Parking Orbits [Freitas and Valdes]
  - * Geocentric Orbits
    - High, Low, Cislunar, Transient [Freitas and Valdes]
  - * Lunar Orbiters or Artifacts [Arkhipov]
  - * Messenger Probes [Bracewell, Freitas]
  - * Dyson Sphere's or O'Neill Colonies [Dyson, O'Neill]

Observable Manifestations of Interstellar Probes

- **Possible Observable Manifestations**
  - Ultraviolet, Visible, and Infrared emissions
  - Soft x-ray or gamma bursts
  - Ionized gases-hot or cold plasmas
  - Anomalous electrophonic, ultrasonic or infrasonic emissions
  - Anomalous telecommunications activity (radio or optical)
  - Radioactivity
  - Varying albedos (radar or optical) from peculiar orbiting structures
  - Physical artifacts or waste products of non-earth origin
  - Visible signs of intelligent macro, micro or nano structural design
  - Unambiguous artificial structures on lunar or other solar system bodies
  - Intelligent and/or autonomous behavior
  - Statistical anomalies in meteor activity or cometary patterns
  - Neutrino emissions

The Search for Interstellar Robotic Probes

- Revisiting the Pros and Cons
  - ∗ PROS
    - The value of robotic exploration of space has been proven
    - Interstellar exploration is within our civilizations grasp
    - Some advanced Type II or III ET civilization's ***will*** explore with robotic probes and produce physical artifacts
    - The search and detection of robotic probes ***can*** be carried out with existing technologies
    - Bi-directional Radio/Optical communication with a probe will be relatively fast
    - Validating the existence of ***one*** probe answers the question: Are We Alone?

The Search for Interstellar Robotic Probes

- Revisiting the Pros and Cons
  - * CONS
    - Interstellar travel is not feasible or practical
    - Interstellar probes are energetically too expensive
    - Interstellar travel takes too long
    - The search space is too big and the search will take too long
    - Instrument technologies are not mature enough to detect a robotic probe or extraterrestrial artifacts
    - The search program will cost too much and be scientifically unproductive
    - Probes have not been detected so they do not exist

Earth's Robotic Probe Launches

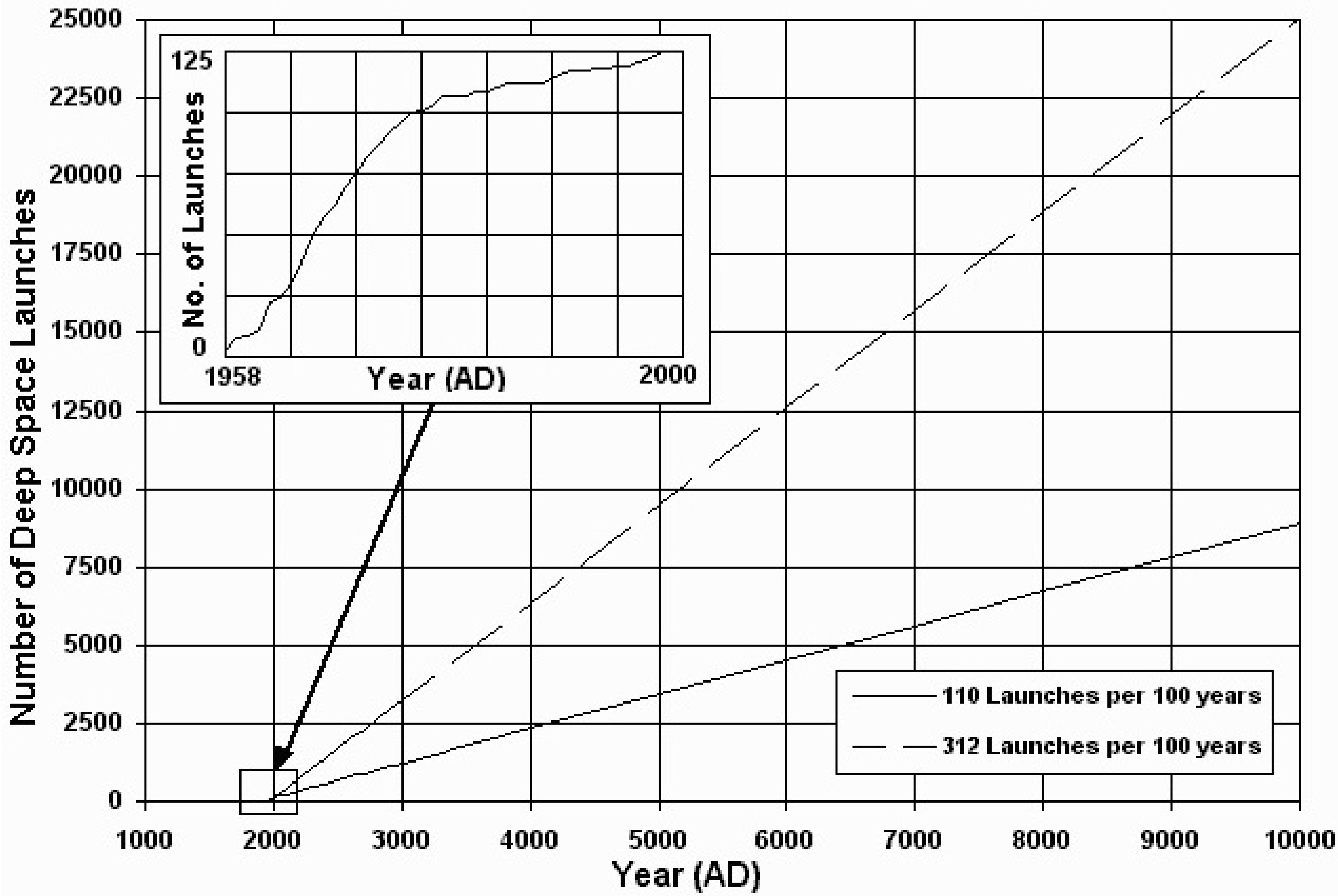


Figure 1. Actual Robotic Probe Launches and Future Projections

Searching for Interstellar Robotic Probes

- Proposed Search Process Steps

1. Decide what robotic robotic probe features to search for.
2. Establish a bounded search volume, artifact size and limiting magnitude.
3. Study the available instruments, sensors, computers, software.
4. Match detectable probe features with the available instruments.
5. Develop a set of design requirements and specifications for an automated or robotic observatory.
6. Select a data management and analysis strategy.
7. Derive experimentally testable hypotheses.
8. Design and build the observatory and begin the search.

* **Concentrate on Detecting Electromagnetic Emissions**

- UV / Visible / IR, Soft X-ray
- Ionized gases, hot or cold plasmas

Searching for Interstellar Robotic Probes

- Define a Robotic Probe Search Space, Size and Limiting Magnitude
  - ∗ **Search volume very large must be satisfactorily bounded**
    - Maximum search distance (d) to sphere of 50 AU solar radii
      - – Large artifacts, high albedo
      - – Possible but very expensive
    - Cislunar 70,000 Km < d < 384,000 Km
    - Exosphere d > 500 Km
    - Stratosphere to Ionosphere 0 Km < d < 350 Km
      - – Possible, preferred and practical with ground based observatories
  - ∗ **Limiting Artifact Size (S_A)**
    - 1 m < S_A < 10 m [Freitas and Valdes]
      - – Based on collision survival, weathering and communication
  - ∗ **Limiting Magnitude (M_L)**
    - -12 > M_L > +11 [Wide FOV, staring array, megapixel CCD, large aperture area]

Searching for Interstellar Robotic Probes

- Make a study of the available Instruments and Sensors
  - Understand the strengths and weaknesses of existing technologies
- Match detectable probe manifestations with available instrument and sensor technologies
  - Choose the correct instruments and sensors for the task
- Develop design requirements for an observatory platform
  - Observatory functionally designed for unattended autonomous or robotic operation
- Why Robotic Observatories?
  - Follows current trends in astronomical observing programs
  - Allows optimal use of scheduling and observing time
  - Minimizes researcher fatigue, stress and boredom
  - Automated data acquisition is more reliable and repeatable
  - Observatory can be used for other (non-SETI) scientific research

Searching for Interstellar Robotic Probes

- Derive experimentally testable hypotheses, for example:

> "*Technologically advanced extraterrestrial civilizations have deployed interstellar exploratory probes, and there is a non-zero probability that functioning probes have reached our solar system and are detectable or contactable using existing terrestrial technologies*." SLS

- Establish a governing set of protocols and procedural documents
- Data Management and Analysis
  - ∗ Observatory raw data must be properly fused, organized and coded
  - ∗ Construct a database of information for mathematical analysis
- Proof is not Real-Time
  - ∗ **A SINGLE OBSERVATION IS NOT GOOD ENOUGH!**
  - ∗ Scientifically acceptable proof of robotic probe technology will depend on using statistical methods on a large set of data

Utilizing Commercial-Off-The-Shelf

- What is COTS?
  - ∗ Off-The-Shelf Instruments, Sensors, Computer Hardware and Software
  - ∗ Mandate established in 1991 to help resolve military hardware obsolescence, supply problems and life-cycle costs
  - ∗ A mechanism for rapidly integrating the newest technologies
- What does COTS mean for SETI?
  - ∗ Variety, Affordability, Flexibility, Modularity, Ruggedization
  - ∗ Systems designed for Performance and Reliability
    - Emphasis on System Functional Test and Validation
    - Reduced Customization
  - ∗ Lower Maintenance, Replacement and Operational costs
  - ∗ Experiments can be replicated by other SETI researchers using the same basic hardware

COTS Instruments

- Instrumentation for Robotic Observatories
  - ∗ Automated Weather Station
    - Localized geophysical and meteorology measurements
  - ∗ GPS Receiver
    - Position-location, time-code, clock reference signals
  - ∗ Optical Telescopes
    - Light gathering and magnification of optical sources
    - Integrated with electronic imaging sensors
  - ∗ Spectrometer or Spectroradiometer
    - Gather wavelength and intensity data on emission spectra
  - ∗ Motorized positioner mounts for optical instruments
    - Pointing or steering of telescope optics and/or sensor arrays
  - ∗ Power Systems
    - Generate portable stand-alone power for the observatory

COTS Instruments

Pan-and-Tilt Positioners

GPS Time and Frequency Receivers

Meteorology Instruments

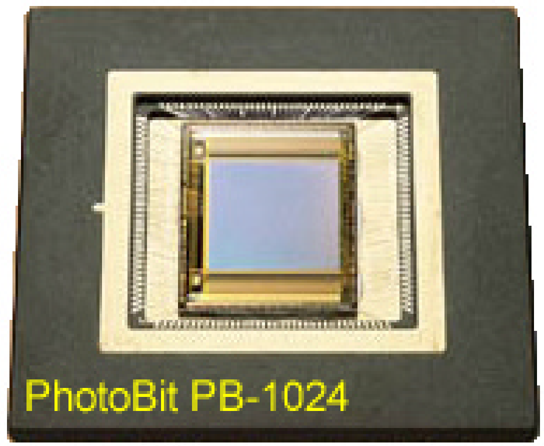
Spectroradiometers

Telescope Optics

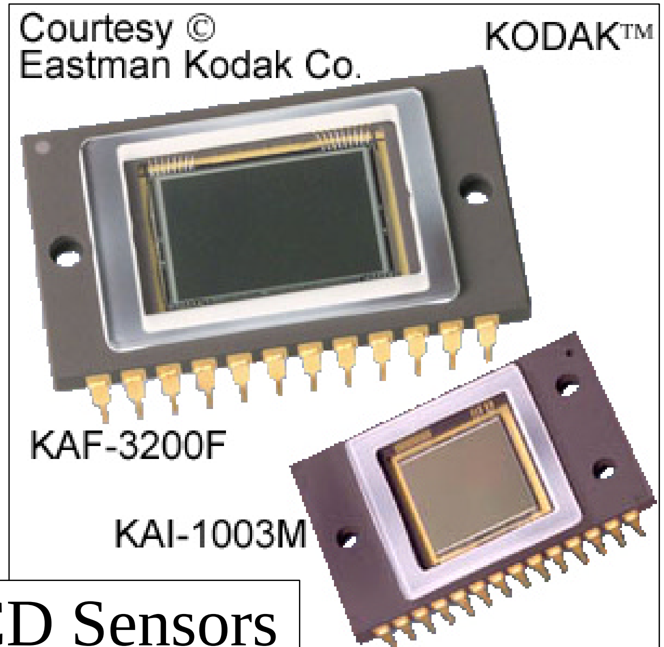
COTS Sensors

- Electromagnetic Spectrum Sensors
  - * CCD (Charge Coupled Devices)
    - Scientific grades, Large apertures, Back-illuminated, High Quantum Efficiency, UV/Visible/NIR Imaging
  - * CMOS APS (Active Pixel Sensor)
    - "Camera-on-a-chip", Digital Output, High Dynamic Range
  - * Microbolometers
    - IR Staring Focal Plane Arrays, $6 < \lambda < 14$ μm, Cooled and Uncooled, IR Imaging
  - * QWIPs (Quantum Well Infrared Photodetectors)
    - IR Staring Focal Plane Arrays, $8 < \lambda < 12$ μm, Narrow or Double-band, Cooled and Uncooled, IR Imaging
- Temperature and Vibration Sensors
    - Thermocouples, RTD, PRT, Thermistor, Semiconductors
    - Miniature accelerometers to monitor platform vibrations

COTS Sensors



CMOS APS



CCD Sensors

QWIPs

Microbolometers

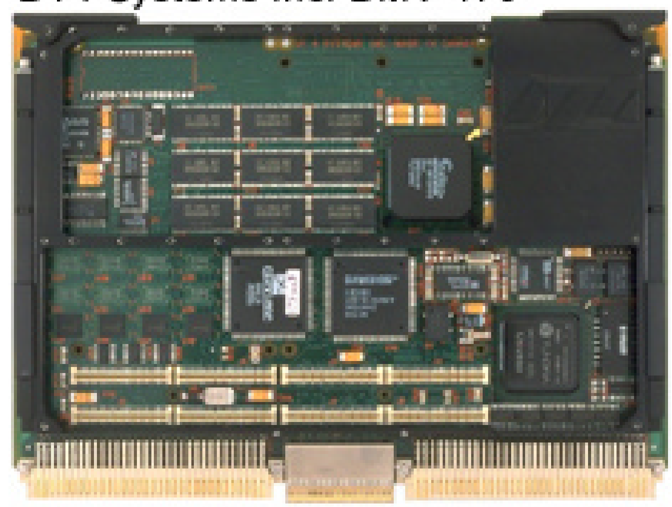
COTS Computer Hardware

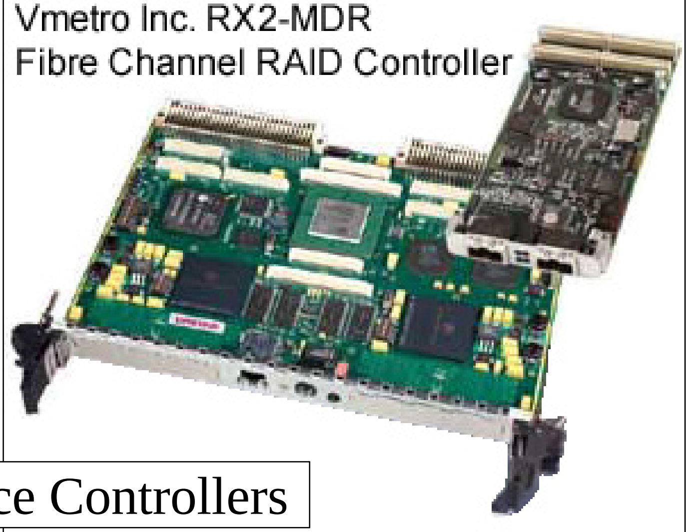
- Modular and Embedded Computing Components
  - ∗ Large Commercial and Military Market
    - Affordable, Reliable Electronic Components
  - ∗ Significant Processing Power and Data Throughput
    - Multiprocessing Computation Capability > 1 Gflop/Sec
    - High Sustained and Burst Data Throughput > 1GB/Sec
  - ∗ Mature, Standard, Modular Bus Architectures and Interfaces
    - VME, cPCI, PC/104+ Bus Interfaces
    - USB, IEEE 1394, RS232/422 Serial Peripheral Interfaces
  - ∗ Embedded Processors
    - 8 and 16-bit microcontrollers perform instrument functions
  - ∗ Ruggedized Chassis for Extreme Environments
    - Robust thermal management and control, low EM emissions

COTS Computer Hardware

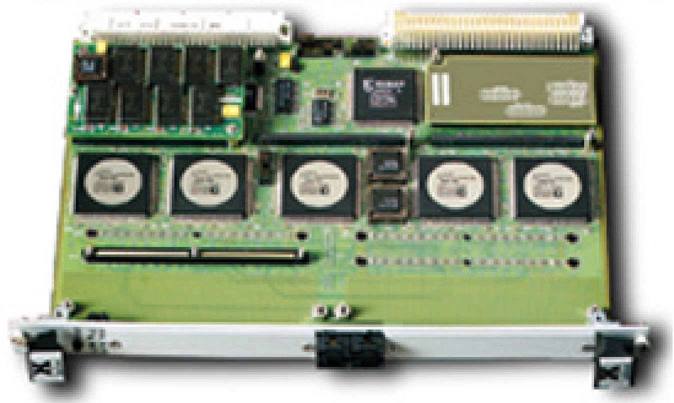
Ruggedized VME Chassis

Single Board Computers





Device Controllers



QUAD DSP VME Board

COTS Computer Software

- Operating Systems
  - ∗ RTOS - Real Time Operating System
    - Deterministic, low latency, low jitter
  - ∗ COTS RTOS
    - POSIX (Portable Operating System Interface) Compliant
    - VxWorks Tornado™, Linux (Real Time Linux)
  - ∗ Why Real-Time?
    - Reliable response to trigger events or sensor generated interrupts
- Instrument Control and Interface Software
  - ∗ LabVIEW™
  - ∗ Peripheral Device Drivers
- Signal Processing Software
- Analysis Software
- Utility Software

The software is the single most critical part of the robotic observatory!

A Robotic Observatory Platform

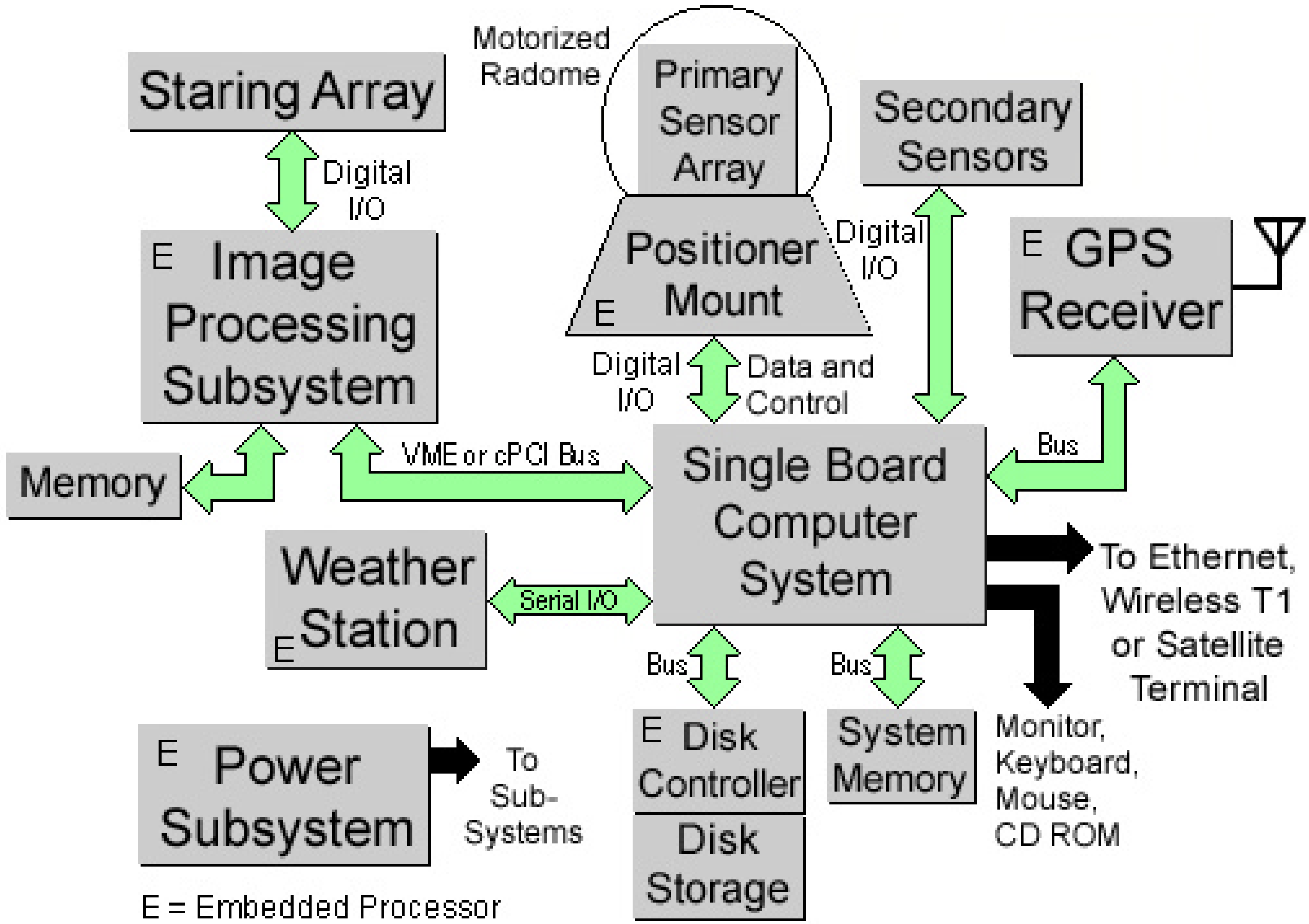


Figure 2. Automated Robotic Observatory Basic System Block Diagram

Summary

1. Robotic probes and artifacts are one possible technological manifestation of Type II & III extraterrestrial civilizations.
2. Robotic probes will possess observable manifestations.
3. The search should focus on electromagnetic emissions.
4. The search space, artifact size and limiting magnitudes must all be bounded parameters.
5. A robotic observatory platform can be designed and built with COTS instruments, sensors, computer HW and SW.
6. Data collected from observatories can be used to test derived hypotheses using statistical methods.
7. A search for robotic probe visitation will require time and patience and determination.
8. SETV is a scientific search for interstellar robotic probes.