Power Subsystem for Extravehicular Activities

Exploration Extravehicular Activity Conference
NASA Clear Lake Hilton
November 15-16, 2005

The NASA Glenn Research Center has the responsibility to develop the next generation space suit power subsystem to support the Vision for Space Exploration. Various technology challenges exist in achieving extended duration missions as envisioned for future lunar and Mars mission scenarios. This paper presents an overview of ongoing development efforts undertaken at the Glenn Research Center in support of power subsystem development for future extravehicular activity systems.

Power Subsystem for Extravehicular Activities for Exploration Missions

Exploration Extravehicular Activity (EVA) Conference
NASA- Clear Lake Hilton
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Power System for Exploration EVA Suits

- Background
- Power Subsystem Team
- Power for Current Space Suit
- AEVA Power Subsystem Development Approach and Status
- Technology Options and Comparison
- Issues and Challenges
- Summary Remarks

Background

- Develop and deliver power subsystems for EVA and AEVA.
- The current priority are the advanced in-space and surface spacesuits.
  - Address all powered elements
  - Interactions with overall suit subsystems
- Power subsystem team members include representatives from Glenn Research Center and Johnson Space Center.

Power Subsystem Team Members

Ken Burke - GRC

Penni Dalton - GRC

Eric Darcy - JSC

Bob Dolesh - GRC

James Fincannon - GRC

Judy Jeevarajan - JSC

Pat Loyselle - GRC

Lisa Kohout - GRC

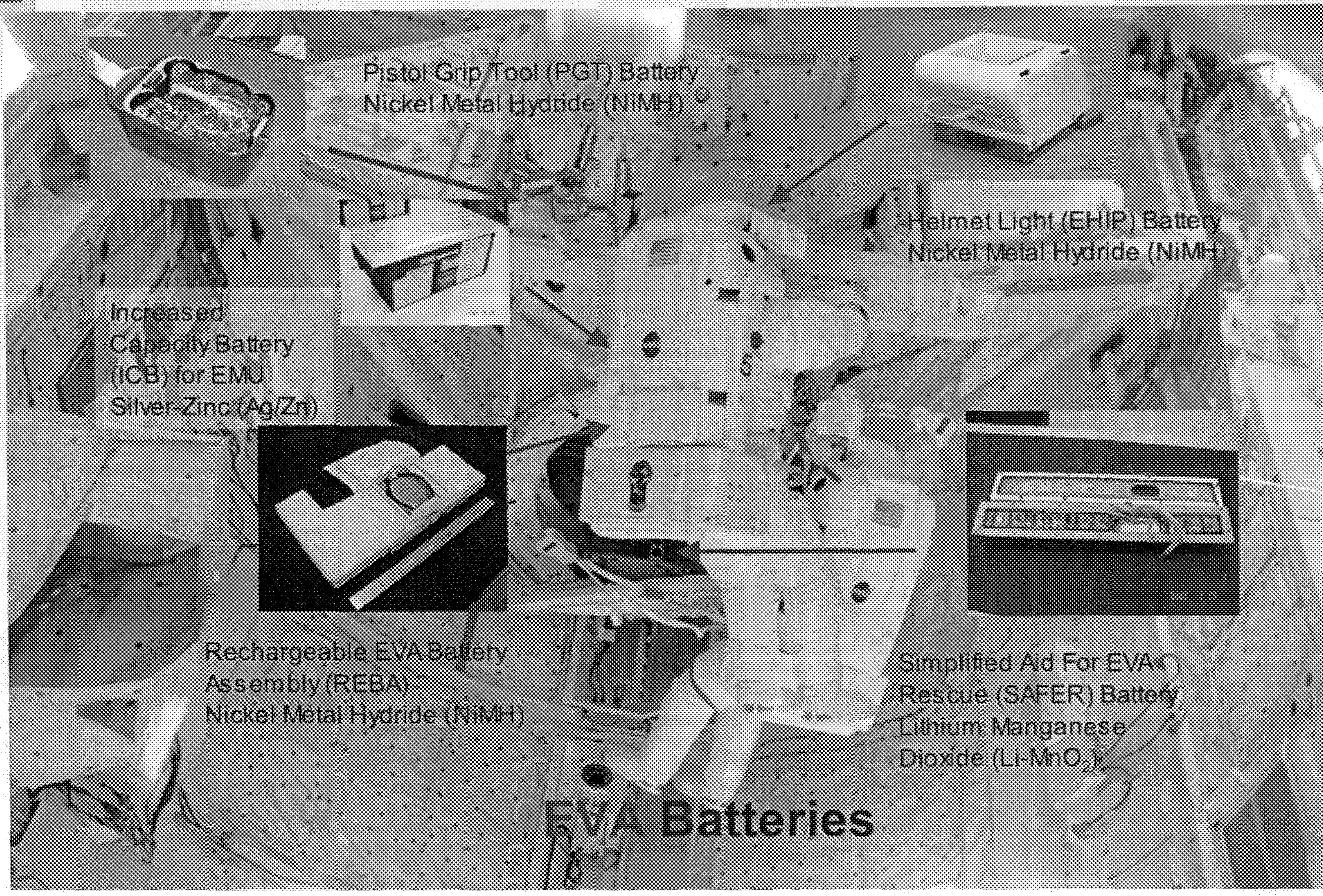
Michelle Manzo - GRC

Barbara McKissock - GRC

Tom Miller - GRC

Concha Reid - GRC

Current EVA Power Systems



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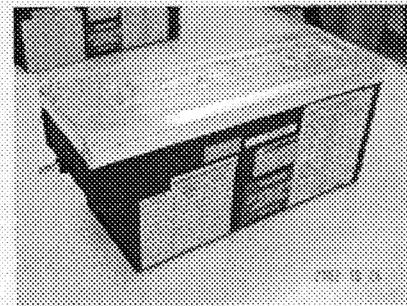
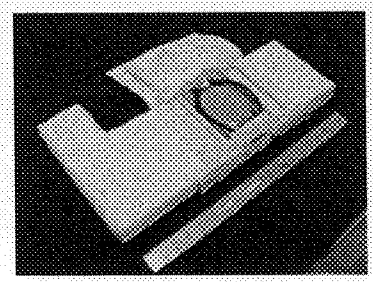
Current EVA Power Systems

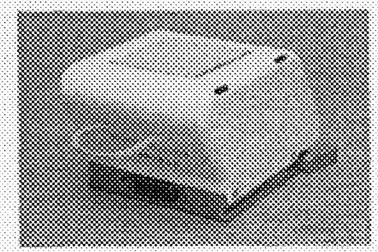
- **Ag-Zn Battery for EMU-PLSS**
  - ~200 Wh/L, 100 Wh/kg
  - ~1 yr calendar life, ~30 cycles
  - High maintenance, high life cycle cost
- **Separate Ni-MH Batteries for**
  - Pistol Grip Tool (PGT)
  - Helmet Light Assembly (EHIP)
  - Glove Heater and Helmet Camera Rechargeable EVA Battery Assembly
    - ~120 Wh/L, ~35 Wh/kg
    - >7 yr calendar life, >500 cycles
    - Passivation issues with dormancy
- **Primary Li/MnO2 Battery for Simplified Aid For EVA Rescue (SAFER)**
  - 200 Wh/L, ~70 Wh/kg
  - Providing >4.5 hrs of runtime when only 13 minutes are needed for self-rescue



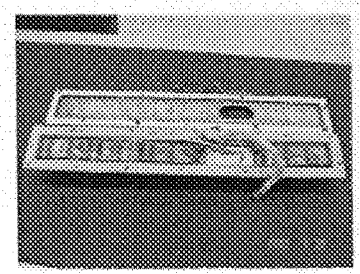
Increased Capacity Battery (ICB) for EMU Silver-Zinc (Ag/Zn)



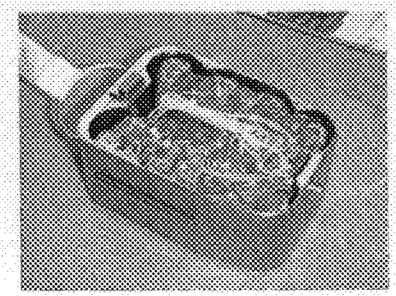
REBA NiMH



EHIP Ni-MH Battery



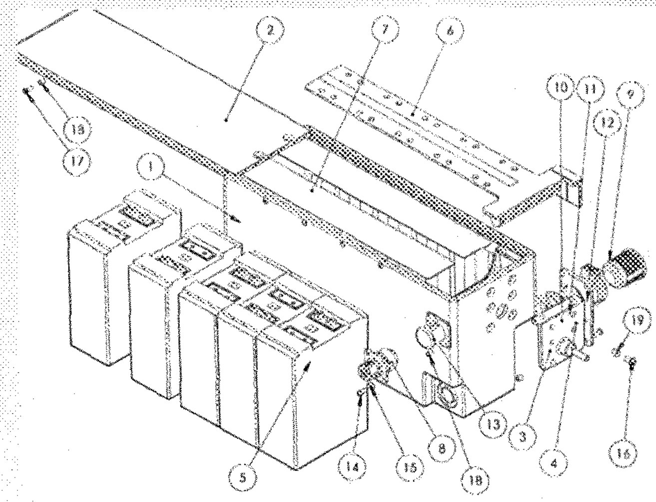
SAFER Li-MnO2 Battery

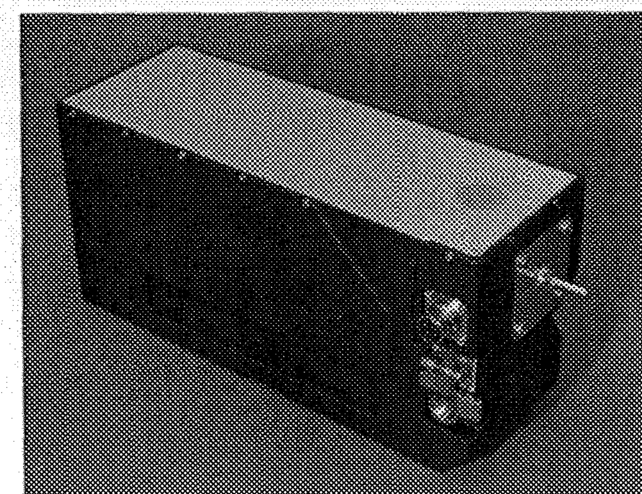


PGT Ni-MH Battery

State of the Art in EVA Batteries

- **New Lithium Ion Polymer Battery for EMU-PLSS**
  - Development started in Oct 03
  - Certification was completed in May 05
  - Scheduled to fly on the next shuttle mission
  - Battery Characteristics
    - >250 Wh/l
    - >125 Wh/kg
    - > 5 year calendar life, 150 cycles
    - Low maintenance and life cycle cost
  - Utilizing pouch cell technology
    - Lithiated carbon anode
    - Lithium cobalt oxide cathode
    - Polymer gel electrolyte/separator construction
    - Plasticized aluminum pouch enclosure

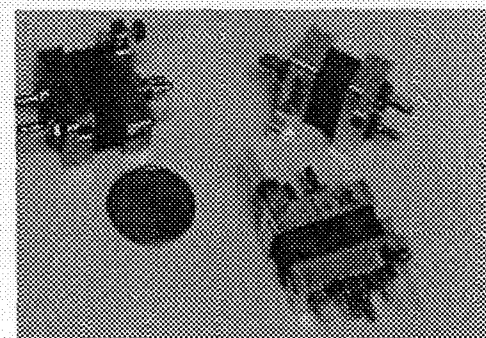




Advanced EVA Suit Power Subsystem

Development of advanced power subsystems to enable extravehicular activities

- EVA (in-space) and AEVA (planetary) astronaut suits
    - Higher power than current space suits
    - Longer run times
    - Commonality between suits
- Power subsystem requirements
    - Light weight – high energy density
    - Compact – high specific energy
    - Long life (500 sorties or more)
    - Low maintenance
    - Quick swap or recharge ability
    - Compatible with planetary and space environments
    - Safe – human rated
    - Modular/reconfigurable for use in other EVA elements (tools, rovers, etc.)



Advanced EVA Suit Power Subsystem

CEV/CLV – In-Space LEO Operations → Lunar Surface Operations → Mars Surface Operations

- Each Phase of Exploration will have more demands on the Electrical Power Subsystem
- Energy Storage is the critical element
  - Specific Energy
  - Energy Density
  - Calendar Life
  - Cycle Life
- Increasing demands will require innovative solutions – departures from current approaches
- Approach to power subsystem development – flexible and adaptable to accommodate technology advances as Exploration program matures

AEVA Power Subsystem Development Approach and Status

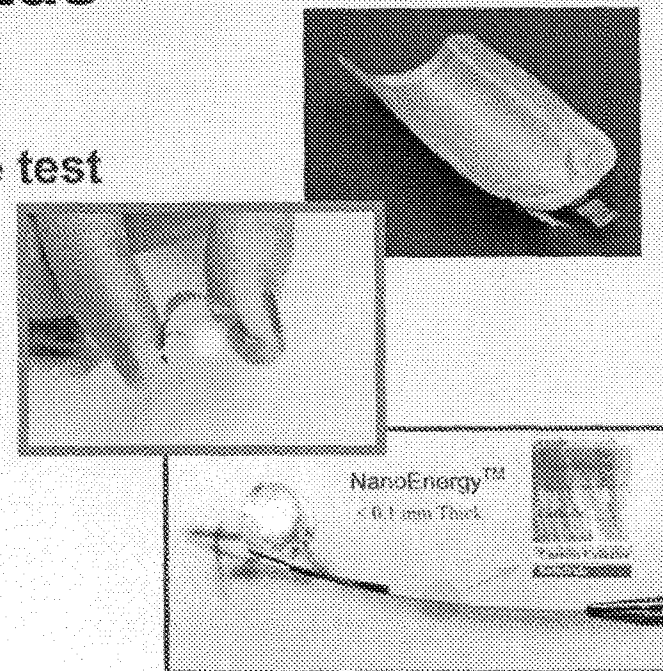
- Assessment
- Perform Trade Studies
  - Solar Augmentation – preliminary analysis completed
  - Localized (distributed) versus centralized power - completed
  - Umbilical versus suit-mounted power - completed
  - Recharge versus replace power source
  - Emergency power
  - Peak Power
  - Fuel Cell versus Battery
  - Inductive Charging versus standard connectors

AEVA Power Subsystem Development Approach and Status

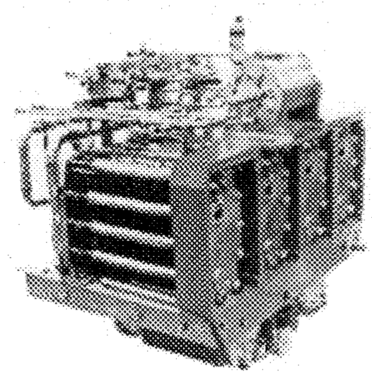
- Integrate with PLSS - Ongoing
  - Schematics
  - Packaging
  - Rapid Recharge
- Develop Power Subsystem
- Requirements and Architecture
  - Identify power requirements from the various suit subsystems
- Technology Assessments and Developments
  - Perform state of the art battery cell evaluations on secondary cells with potential to meet AEVA requirements
  - Perform preliminary evaluation of fuel cell options
  - Perform technology development tasks to meet AEVA specific needs
  - Power subsystem interfaces – thermal, electrical

AEVA Power Subsystem Development Approach and Status

- Battery Evaluation
  - Standardize testing performance and abuse test procedures for SOA cell assessment
    - Custom made cells
    - Multiple Chemistries
    - Multiple Vendors
  - Technology Tasks to address
    - Rapid recharge capability
    - Improved safety and abuse tolerance
    - Increased operating temperature range



- Fuel Cell Evaluation
    - Proton Exchange Membrane
    - Solid Oxide Fuel Cell
    - Evaluate micro fuel cell options
    - Overall PLSS integration



Power Subsystem
Energy Storage Technology Options

Battery Systems

- Li-Ion Batteries
- Li-Polymer Batteries
- Conformal batteries
- Structural Batteries
- Thin Film, Solid State Batteries
- Zinc-Air/O_2, Li-Air/O_2

Fuel Cell Systems

- Proton Exchange Membrane
- Direct Methanol Fuel Cells
- Solid Oxide Fuel Cells
- Integration with Life Support Systems

Hybrid Systems

- Battery/Fuel Cell/Capacitor

Augmented Storage Systems

- Solar augmentation – Arrays, PV fibers

Charging Techniques

- Inductive charging

Power Subsystem
Energy Storage Technology Comparison

	Pros	Cons
Batteries	• Higher TRL for space applications (6-8) ○ Multiple chemistries developed for and flown in space environment • Simple device – no moving parts - all reactants and products are contained within the battery housing • High volumetric energy density (Wh/l) • High roundtrip efficiency • Multiyear cycle life demonstrated	• Application specific development needed • Requires electrical recharge process which can be slow • Capacity (run time) directly related to weight and volume
Fuel Cells	• Operates with continuous feed of reactants from external storage – unlimited capacity if source of reactants • Can be recharged via reactant resupply (fast) • For long run times - high gravimetric energy density (Wh/kg) • Potential to interface with portable life support systems ○ Oxygen ○ C O_2 Removal • Reactants can be regenerated from products via electrolysis • Potential for in-situ production of reactants	• Lower TRL for space applications (2-3) ○ Small, compact fuel cells have not been developed or flown in space environment • Application specific development needed • Liquid reactant storage requires reformer/processors to extract vapor fuel from liquid • Limited life demonstrated • Thermal interfaces and heat rejection • Water management issues in Zero G • Durability issues

Power Subsystem Issues and Challenges

- Must be designed for the harsh environments of space and surface
  - High/low Temperature extremes
  - Radiation tolerance
  - Dust contamination
- Must have improved performance over current system
  - Higher energy density
  - Higher specific energy
  - Higher efficiency
  - Longer storage and operational life
  - Lower maintenance
  - Faster recharge/swap out
- Human-rated safety certification required

Summary Remarks

- Close coordination with other Suit subsystems required during process of development of Power Subsystem Concept of Operation, Requirements and Architecture
- Abbreviated timeframe for Constellation is the driver for the use of current SOA or extremely near-term technologies for in-space applications
  - Strategy is to evaluate custom-made and COTS cells and batteries, and to perform technology development where needed to address performance and human-rated safety issues identified through technology evaluations
- Farther out Explorations Systems targets allow for longer term development efforts and as identified through the evaluation of lower TRL technologies