Man-Packable Power Systems

Assessment of Alternative Fuel Cells
(Current and Future Technologies)

Part 2 of 2

(Future Technologies)

Joint Service Power Expo

May 2-5, 2005
Tampa Convention Center

Tampa, Florida

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Outline

- **Identify & Assess Some of DoD's Near Term Man Packable Fuel Cell Technologies**
  - **Targeted as Primary Power Sources**
  - **Targeted as BB-2590 Battery Chargers**
- **Address Maturity of Technologies**
- **Compare Physical/Electrical Properties**
- **Identify Environmental Limitations**
- **Chart Volumetric/Gravimetric Requirements**
- **Provide Conclusions & Recommendations**

Acknowledgements

- **Mr. Nick Sifer (CERDEC – Ft Belvoir)**
  - **Ultra Cell xx90 EVT 45W RMFC**
- **Major Alan Stocks (ONR Code 353)**
  - **Mesoscopic Devices MesoGen-250 250W SOFC**
- **Dr. Deryn Chu (ARL – Adelphi, MD)**
  - **Mesoscopic Devices MesoGen-20 20W DMFC**
- **Dr. Valerie Browning (DARPA)**
  - **Adaptive Material Inc Gen 2 20W SOFC**
  - **Mesoscopic Devices MesoGen-75 75W DMFC**

Acknowledgements

- **Captain David Pfahler (AFRL WPAFB)**
  - **Protonex DUS&T P2 30W PEMFC**
- **Mr Christian Böhm – SFC**
  - **Smart Fuel Cell C50 DMFC**

Technologies Assessed

Ultra Cell XX90 EVT

45W RMFC, 12VDC

Target Application – Primary Power Source

DoD Lead Activity – CERDEC

Fuel – 67/33 vol% Methanol/H_2O

TRL – 3-4

Adaptive Material Inc GEN 2

20W SOFC, 12 VDC

Target Application – Primary Power Source

DoD Lead Activity – DARPA

Fuel - Propane/Butane

<1000ppm sulfur

22ppm typical

TRL – 3- 4

Protonex DUS&T P2

30W PEM, 12 VDC

Target Application – Battery Charger

DoD Lead Activity – AFRL

Fuel - 20-25% Sodium Borohydride

3% Sodium Hydroxide

72-77% De-Ionized H_2O

TRL – 3- 4

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Mesoscopic Devices MesoGen-20

20 W DMFC, 12 VDC

Target Application – Primary Power Source

DoD Lead Activity – ARL

Fuel - 100% Methanol

TRL - 4

Mesoscopic Devices MesoGen-75

75 W SOFC, 12 VDC

Target Application – Battery Charger

DoD Lead Activity – DARPA

Fuel - Sulfur Free JP-8

TRL - 3

Mesoscopic Devices MesoGen-250

250 W SOFC, 12/24VDC

Target Application – Battery Charger

DoD Lead Activity – ONR/USMC

Fuel - JP-8

Desulfurizer to <15ppm

TRL - 2

Maturity Of Technologies

- **SFC C50 - TRL 2/3**
  - **First Generation Prototype Under Internal Development projected availability is 10/05**
  - **Components Alpha Unit In Test, 1800 Hr Internal Demonstration**
  - **System Projected 5000 Hr**
- **Ultra Cell XX90 EVT – TRL 3/4**
  - **First Generation Prototype To Be Delivered To CERDEC 10/05**
  - **Alpha Unit Components In Test, 1800 Hr Internal Demonstration**
  - **System Life Projected 5000Hr**
- **AMI Gen 2 – TRL 3/4**
  - **Generation 2 Prototype To Be Delivered To DARPA 12/06**
  - **System/Stack Gen 1.9 In Test, 100+/300+ Hr Internal Demonstration**
  - **System Projected 2000 Hr**

Maturity Of Technologies

- **Protonex DUS&T P2 - TRL 3/4**
  - **Second Generation Prototype Delivery Scheduled 10/05**
  - **P1 System/Stack In Test, 100+/4000+ Hr Internal Demonstration**
- **Mesoscopic MesoGen-20 DMFC – TRL 4**
  - **First Generation Prototype To Be Delivered To ARL Fall 05**
- **Mesoscopic MesoGen-75 SOFC – TRL 3**
  - **Generation 2 Prototype To Be Delivered To DARPA 6/05**
- **Mesoscopic MesoGen-250 SOFC – TRL 2**
  - **Contract Award 3/05**
  - **First Gen Prototype To Be Delivered To ONR/USMC 2008**

Projected Physical Properties

Manufacturer	Total Unit Volume (cc)	Base Unit Volume (cc)	Auxiliary Unit Volume (cc)	Wet Weight (kg)	Dry Weight (kg)	Auxiliary Weight (kg)
Giner 120 (Today's Unit)	14, 287	14, 287	250	9.00	8.80 (H2O res)	0.20
SFC 50 (C50)	2,812	2,312	500	2.47	2	0.47
AMI 20 (Generation 2)	3,021	2,043	978	1.30	0.80	0.50
Protonex 30 (DUS&T P2)	1,730	980	750	2.20	0.75	1.45
Meso 20 (Meso Gen-20)	1,400	1,150	250	1.10	0.86	0.24
Meso 75 (Meso Gen-75)	5,850	5,200	650	3.58	3.00	0.58
Meso 250 (Meso Gen-250)	14,700	12,000	2,700	6.40	4.00	2.40
UltraCell EVT (XX90 EVT)	1,920	1,420	500	1.57	1.00	0.57

Blue – Data For Today's Technology

Projected Electrical Properties

Manufacturer	Capacity Of One Container @ Rated Cap (W-Hrs)	Fuel Consumption (Kg/KWh)	Nominal Voltage (VDC)	Cold Start (Seconds) 75%	Cold Start (Seconds) 100%	Hybrid Design (Battery)
Giner 120 (Today's Unit)	192	1.29	12	<300	300	--
SFC 50 (C50)	480	0.98	12/24	120	150	10-100Wh
AMI 20 (Generation 2)	820	0.49	12	<900	<900	Li-Poly 23Wh
Protonex 30 (DUS&T P2)	720	2.05	12	<45	<45	3 Ni-Cd 0.9 Wh
Meso 20 (Meso Gen-20)	316	1.34	12	<600	<600	TBD
Meso 75 (Meso Gen-75)	1,530	0.48	12	<900	<900	TBD
Meso 250 (Meso Gen-250)	6,000	0.48	24	<900	<900	TBD
UltraCell 45 (XX90 EVT)	480	1.20	12	TBD	TBD	Li-Ion 7.4Wh

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Projected Environmental Limitations

Manufacturer	Storage T/H (C, %RH)	Operating T/H (C, %RH)	Operating Altitude (Kft)
Giner 120 (Today's Unit)	TBD	TBD	TBD
SFC 50 (C50)	-35 to 55	-20 to 50	10K
AMI 20 (Generation 2)	-40 to 70 0 to 100%	-40 to 60 0 to 99+%	20K
Protonex 30 (DUS&T P2)	TBD 0 to 100%	-20 to 50 0 to 100%	>10K
Meso 20 (Meso Gen-20)	0 to 40 TBD	0 to 40 TBD	10K
Meso 75 (Meso Gen-75)	-20 to 60 TBD	-20 to 60 TBD	10K
Meso 250 (Meso Gen-250)	-20 to 60 TBD	-20 to 60 TBD	10K
UltraCell 45 (XX90 EVT)	-31 to 49 0 - 100	-31 to 49 0 - 100	5K

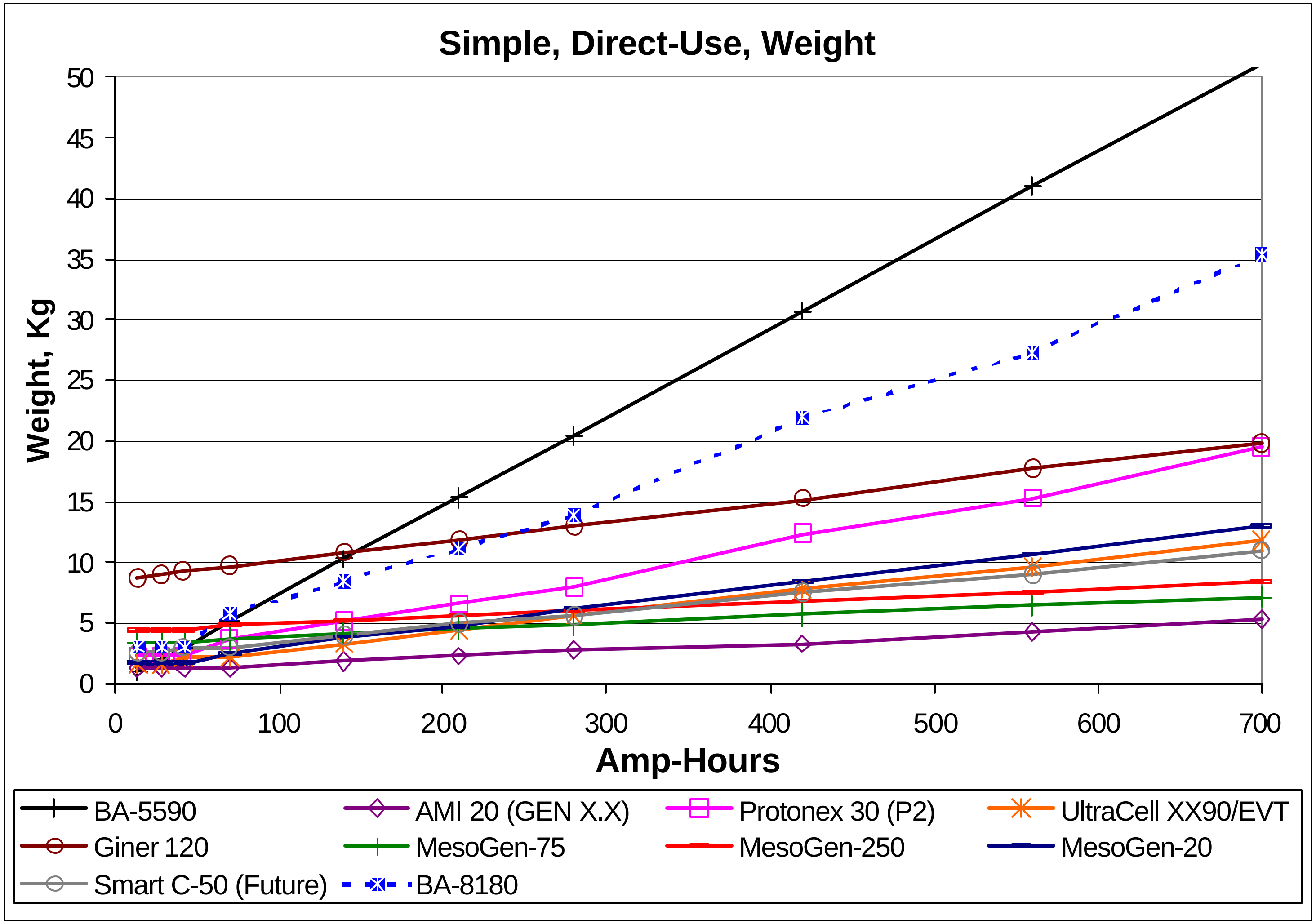
All Data Provided By Mfg/Spec Sheet

Blue – Data For Today's Technology

Simple Direct-Use Assumptions

- **Simple 12V Direct-Use Application**
  - **Direct-Use as Power Supply**
  - **Power Provided Assumed Adequate for Mission**
  - **Continuously Operate @ Full Power**
  - **Weight/Volume Increments Only With Fuel Refills**

Simple Direct-Use Gravimetric Comparison



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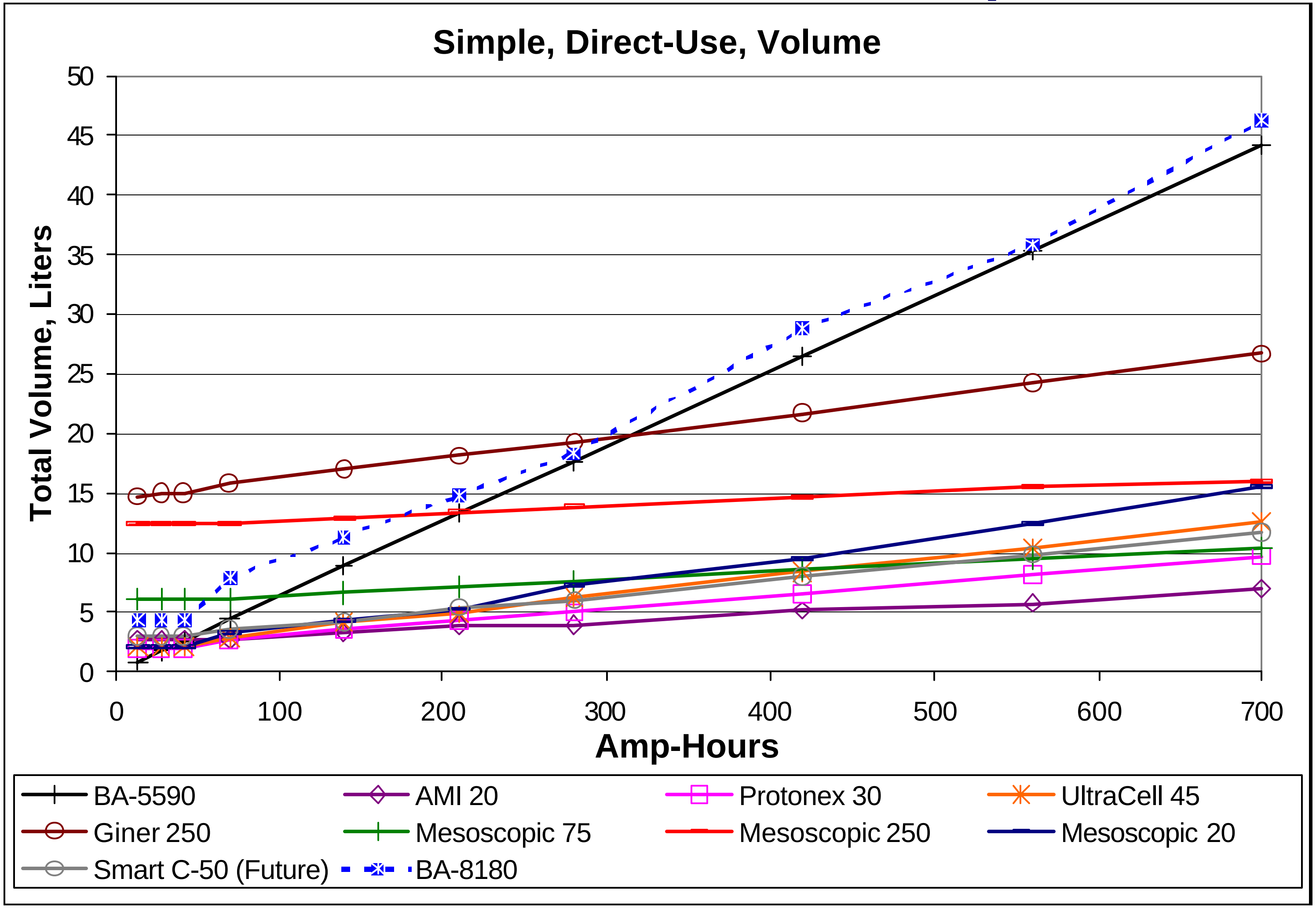
Simple Direct-Use Volumetric Comparison



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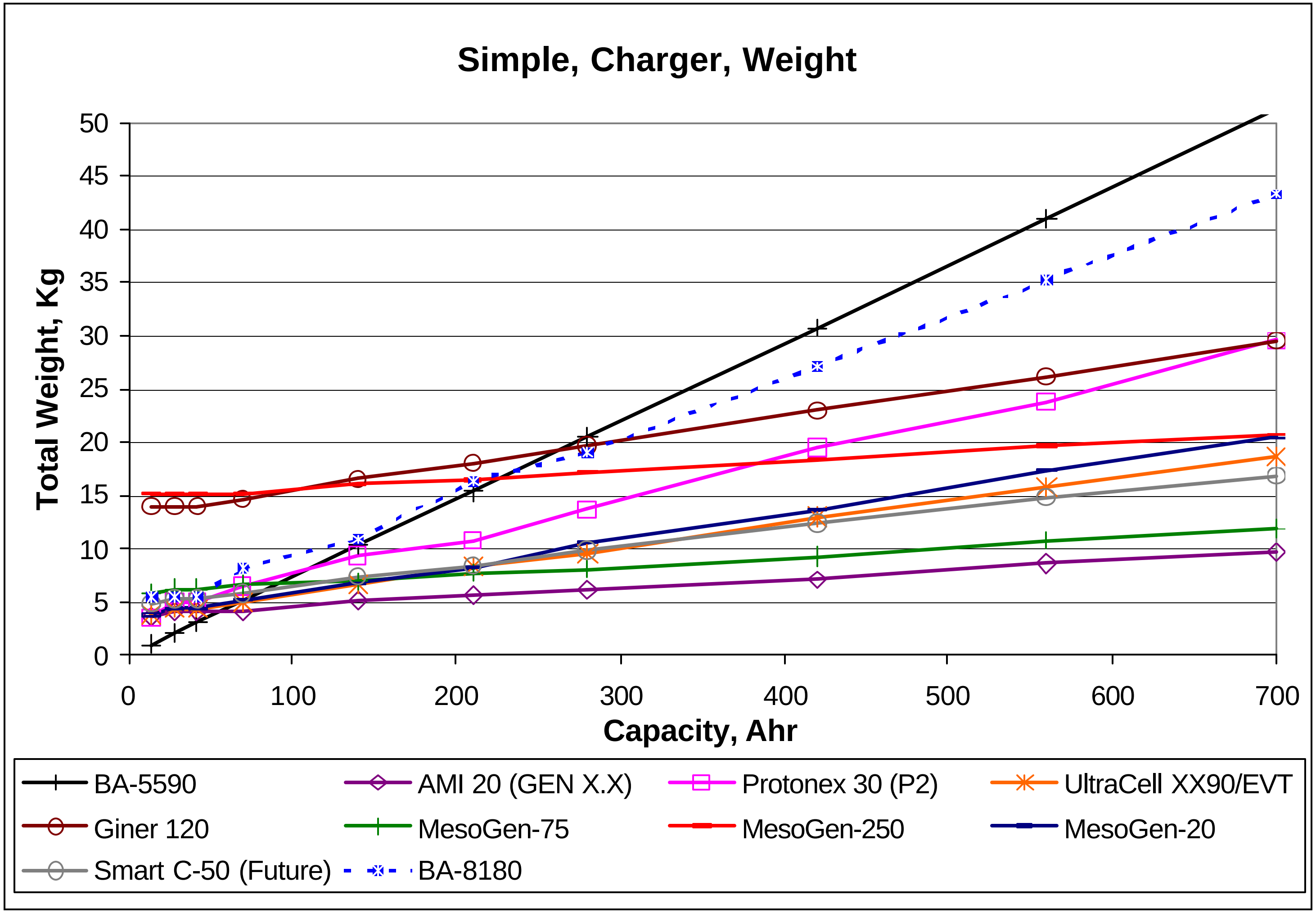
Simple Charger Assumptions

- **Simple 12V Battery Charger Application**
  - **All Batteries Fully Charged Before Starting Mission**
  - **Power Provided Adequate for Mission**
  - **Two BB-2590's Required For Each 75W Provided**
    - **Round Up**
  - **Continuously Operate Fuel Cell @ Full Rated Power**
    - **Charging First Battery as Second Battery is Discharged**
  - **Constant Voltage Charge BB 2590's Only**
    - **Charge Control Circuit Weight & Volume Omitted**
  - **69% Efficient Charge Cycle**
    - **0.85 Battery Charge Eff X 0.9 Charge Circuit Eff X 0.9 Charger Power Utilization**
  - **Weight & Volume Increment Only With Fuel Refills**

Simple Charger Gravimetric Comparison



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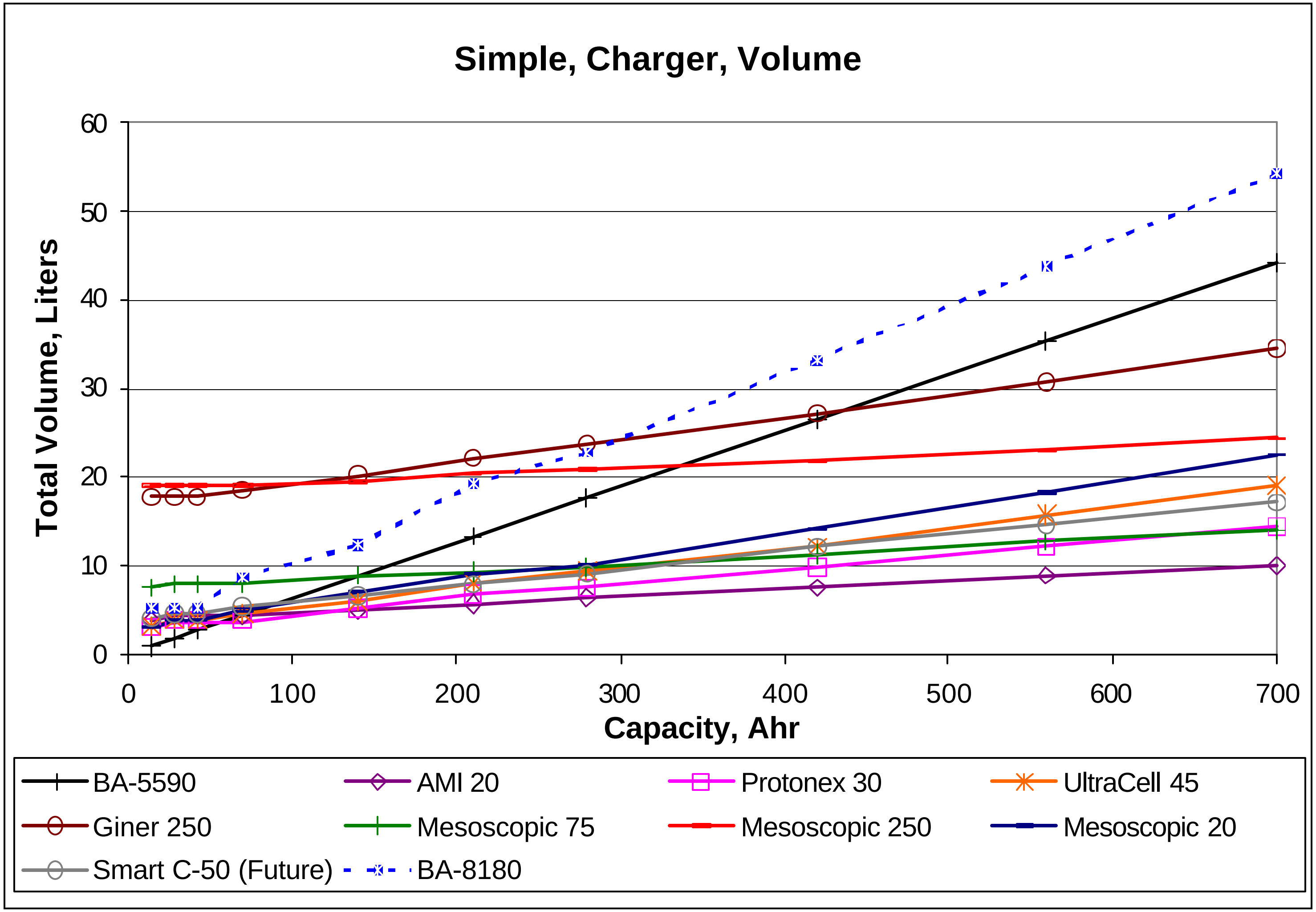
Simple Charger Volumetric Comparison



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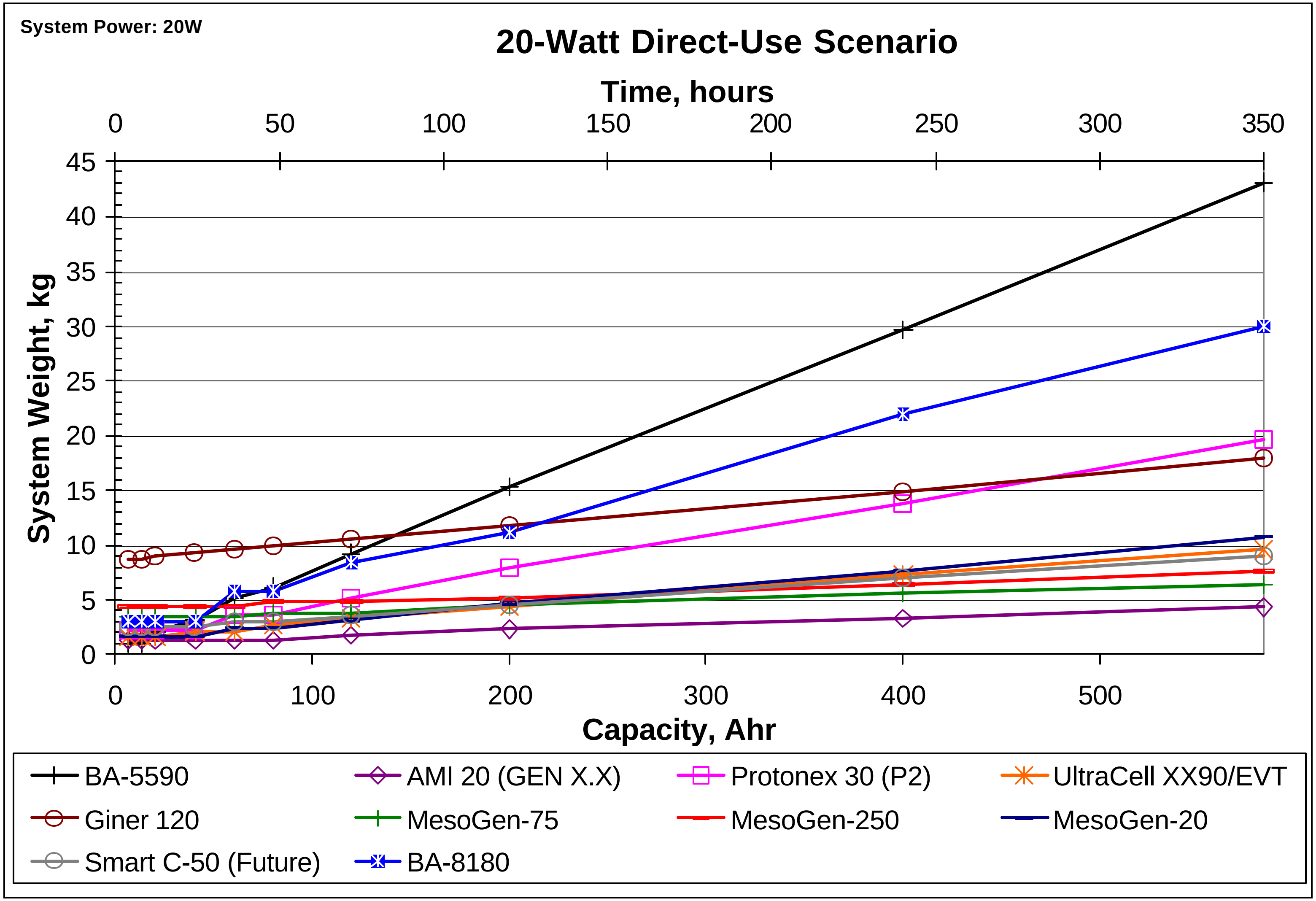
Primary Scenario Assumptions

- **12V Primary Power Scenarios**
  - **Direct Use as Power Supply**
  - **Fuel Cells Incremented to Meet Power**
    - **Two 20W Fuel Cells Required for 40W mission**
  - **Fuel Incremented to Meet Energy**
  - **Weight/Volume Increments With Fuel Cells And Fuel Refills**
    - **Data Points Graphed at Target Durations**
      - 4hr, 8hr, 12hr, 16hr, 24hr, 36hr, 48hr, 60hr, 72hr, & 120hr+

20W Direct-Use Scenario



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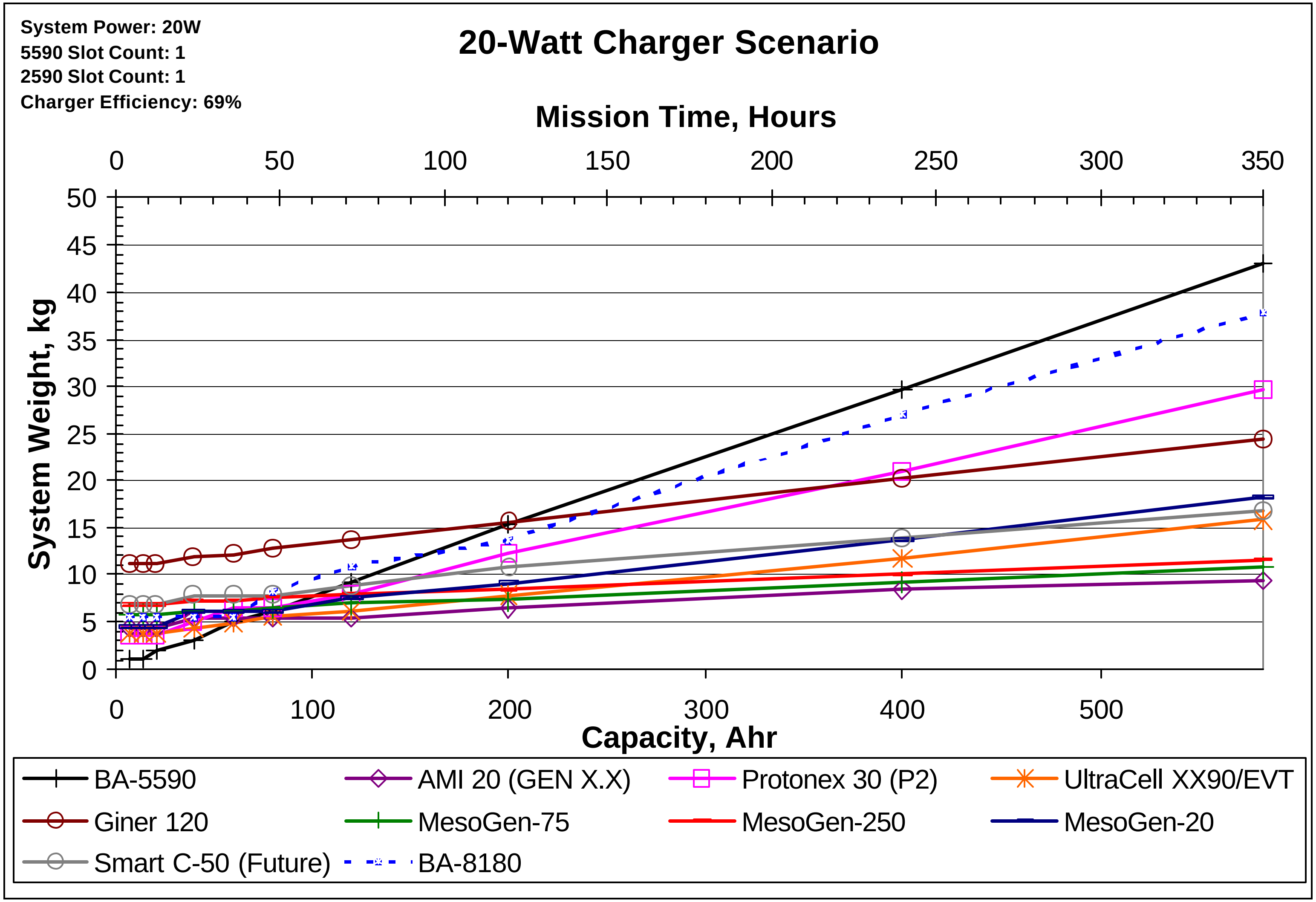
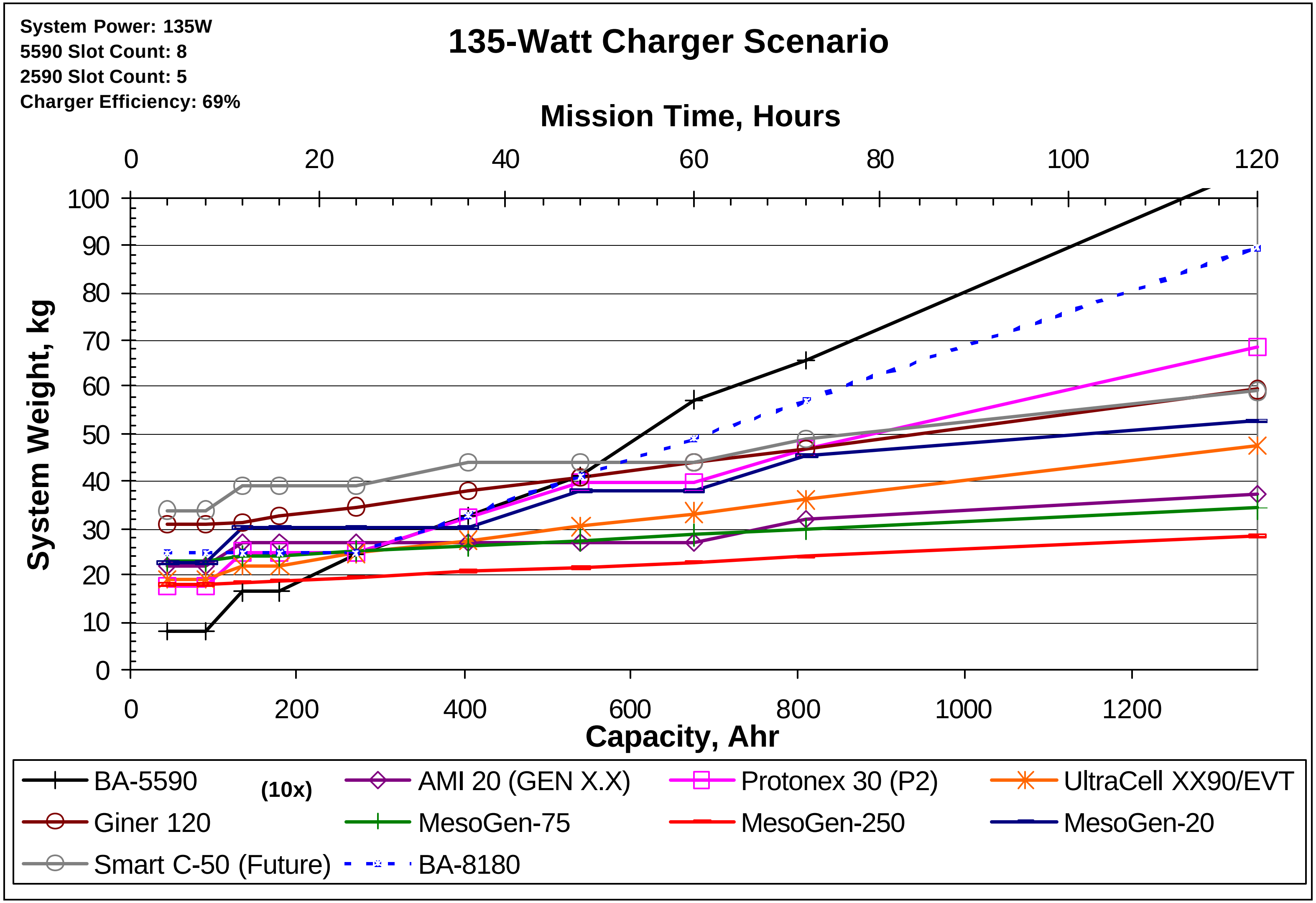
Charger Scenario Assumptions

- **12V Battery Charger Scenarios**
  - **BB-2590's Replace BA-5590 By Power**
  - **All Batteries Fully Charged Before Starting**
  - **69% Charge Cycle Efficiency**
  - **Charger Power Keeps Pace With Mission Requirements By Adding Fuel Cells**
  - **Weight/Volume Increments Only With Fuel Refills**
    - **Data Points Graphed at Target Durations**
      - 4hr, 8hr, 12hr, 16hr, 24hr, 36hr, 48hr, 60hr, 72hr, & 120hr+

20W Charger Scenario

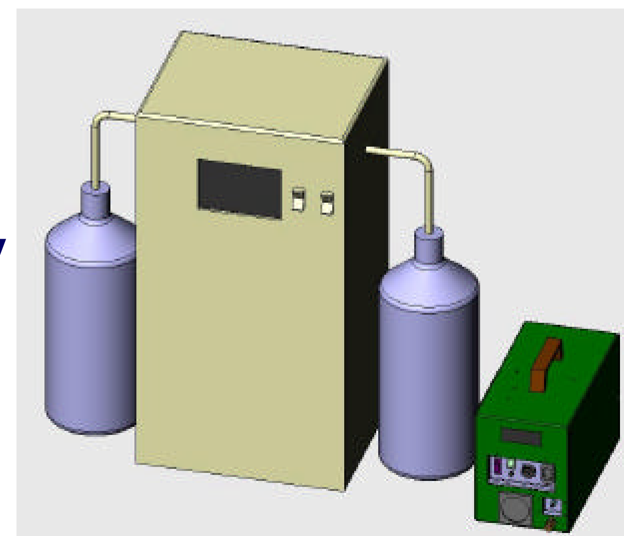


135W Charger Scenario



NAVSEA Desulfurizer

- **ONR/USMC (Major Stocks)**
  - **Sub To ONR Electric Ship Development**
  - **TRL ~ 4 (Mesoscopic Devices)**
  - **0.5 - .75 L/Hr, 3-15 ppm**
  - **Prototype Delivery 2008**
- **Multi-bed system**
  - **Single Rotating Valve**
  - **Maximizes Sorbent Efficiency**
  - **Air Regenerable Sorbents**



Conclusions

- **Projections Do Not Account For Design Maturities**
- **Pros and Cons of Each Technology Should be Closely Considered for Each Application**
- **Actual Performance Data at Specific Power Levels Will Improve Quality of Projections**
- **Using Bulk Refill Container(s) for Commodity Fuels Will Level Playing Field (Container Selection)**
- **Power Management Systems & Charge Circuit Technologies Need Advancement**