Man-Packable Power Systems An

Assessment of Alternative Fuel Cells (Current and Future Technologies)

Part 1 of 2

(Current Technologies)

Joint Service Power Expo

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Outline

- **Identify & Assess Some of DoD's Leading Man Packable Fuel Cell Technologies**
  - **Targeted as Primary Power Source**
  - **Targeted as Battery Chargers**
- **Address Maturity of Technologies**
- **Compare Physical/Electrical Properties**
- **Identify Environmental Limitations**
- **Chart Volumetric/Gravimetric Requirements**
- **Look at Technology Pro's and Con's**
- **Provide Conclusions**

Acknowledgements

- **Mr. Nick Sifer (CERDEC – Ft Belvoir)**
  - Smart Fuel Cell C20 20W DMFC
  - UltraCell XX90 Alpha 45W RMFC
- **Captain David Pfahler (AFRL – WPAFB)**
  - Protonex DUS&T P1 30W PEMFC
- **Dr. Deryn Chu (ARL – Adelphi, MD)**
  - Giner GES 120W DMFC
- **Dr. Valerie Browning (DARPA)**
  - Adaptive Material Inc Gen 1.9 20W SOFC
- **Mr. Christian Böhm (SFC)**
  - Smart Fuel Cell A50 50W DMFC

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Technologies Assessed

BA-5590

12/24 VDC Non-Rechargeable Lithium Sulfur Dioxide

Target Application – Primary Portable Power

DoD Lead Activity – All

Fuel - NA

TRL – 9 (In Service)

BB-2590

12/24 VDC Rechargeable Li-Ion Battery

Target Application – Primary Power Source

DoD Lead Activity – All

Fuel - NA

TRL – 9 (In Service)

BA-8180/U

15/30 VDC Non-Rechargeable Zinc Air

Target Application – Battery Charger

DoD Lead Activity – Army

Fuel - Air

TRL – 9 (In Service)

Smart Fuel Cell C20-MP

SFC C20-MP, 12 VDC

Target Application – Primary Power Source

DoD Lead Activity – CERDEC

Fuel - 100% Methanol

TRL - 5-7

Smart Fuel Cell A50

50W DMFC, 12/24 VDC

Target Application – Battery Charger

Lead Activity – SFC IR&D

Fuel - 100% Methanol

TRL – 7- 8

UltraCell XX90 ALPHA

45W RMFC, 12 VDC
Target Application – Primary Power Source

DoD Lead Activity – CERDEC

Fuel - 67/33 vol% Methanol/H_2O

TRL – 4-5

Adaptive Material Inc GEN-1.9

20W SOFC, 12 VDC

Target Application – Primary Power Source

DoD Lead Activity – DARPA

Fuel - Sulfur Free Propane

TRL – 4-5

Protonex DUS&T P1

30W PEMFC, 12 VDC

Target Application – Battery Charger

DoD Lead Activity – AFRL

Fuel - 16-20 wt% Sodium Borohydride

3% Sodium Hydroxide

77-81% De-Ionized H_2O

TRL - 4-5

Giner GES 120

120 W DMFC, 12VDC

Target Application – Battery Charger

DoD Lead Activity – ARL

Fuel - 100% Methanol

Internal H_2O Reservoir

TRL – 4-5

Maturity Of Technologies

- **Ultra Cell XX90 Alpha – TRL 4/5**
  - First Generation Prototype Delivered To CERDEC 4/05
  - Components In Test, 1800 Hr Internal Demonstration
- **AMI Gen 1.9 – TRL 4/5**
  - Generation 1.9 Demonstration Summer 05
  - System/Stack In Test, 100+/300+ Hr Internal Demonstration
- **Protonex DUS&T P1 – TRL 4/5**
  - First Generation Prototype Delivered AFRL 2/05
  - System In Test, 200+ Hr on SBH, 1000+ Hr on H_2 Demonstrated
  - Stack In Test, 4000+ Hr Internal Demonstration

Maturity Of Technologies

- **Giner GES 120 – TRL 4/5**
  - **Prototype Delivered 1/04 Under Evaluation @ ARL**
  - **System >200 Hr Demonstrated**

- **SFC C20 – TRL 5/7**
  - **Second Generation Prototype Delivered CERDEC 4/05**
  - **System/Stack Internal Demonstration 1650+/2000+ Hr**

- **SFC A50 – TRL 7/8**
  - **Commercial Variety Available, Military TRL Varies With Specific Applications**
  - **System/Stack Internal Demonstration 3000+/4000+ Hr**

Physical Properties

Manufacturer	Total Unit Volume (cc)	Base Unit Volume (cc)	Auxiliary Unit Volume (cc)	Wet Weight (kg)	Dry Weight (kg)	Auxiliary Weight (kg)
BA 5590/U (MIL Power)	883	883	NA	1.03	1.03	NA
BA 8180/U (AROTECH)	3,913	3085	828	3.05	2.7	0.35
BB 2590/U (Bren-Tronics)	868	868	NA	1.4	1.4	NA
SFC 20 C20-MP	2,8312	2,312	500	2.47	2	0.47
SFC 50 A50	19,820	14,820	5,000	10.3	6	4.30
AMI 20 Generation 1.9	4,433	3,455	978	1.79	1.29	0.50
Protonex 30 (DUS&T P1)	2,306	1,226	1,080	2.33	1.08	1.25
UltraCell 45A (Alpha Prototype)	1,770	1,270	500	1.77	1.20	0.57
Giner 120 (GES 120)	14, 287	14, 287	250	9.00	8.80 (H2O res)	0.20

Clear - Data Measured/Witnessed by Gov

Green - Test Data Provided by Mfg

Yellow – Data Provided by Mfg/Spec Sheet

Electrical Properties

Manufacturer	Capacity per fill or charge @ Rated Cap (W-Hrs)	Fuel Consumption (Kg/KWh)	Nominal Voltage (VDC)	Cold Start (Seconds) 75%	Cold Start (Seconds) 100%	Hybrid Design (Battery)
BA 5590 (Brentronix)	170	NA	12/24	<1	<1	NA
BA 8180/U (AROTECH)	800	NA	12/24	TBD	TBD	NA
BB 2590 (Brentronix)	160	NA	12/24	<1	<1	NA
SFC 20 C20-MP	471	0.98	12	120	150	Li-Poly 18Wh
SFC 50 A50	5,544	0.81	12	482	677	NA
AMI 20 Generation 1.9	520	0.83	12	1016	1042	Li-Poly 23Wh
Protonex 30 (DUS&T P1)	927	2.05	12	45	45	3 Ni-Cd 0.9 Wh
UltraCell 45A (Alpha Prototype)	390	1.45	12	TBD	TBD	Li-Ion 7.4Wh
Giner 120 (GES Prototype)	192	1.29	12	<300	300	--

Clear - Data Measured/Witnessed by Gov

Green - Test Data Provided by Mfg

Yellow – Data Provided by Mfg/Spec Sheet

Environmental Limitations

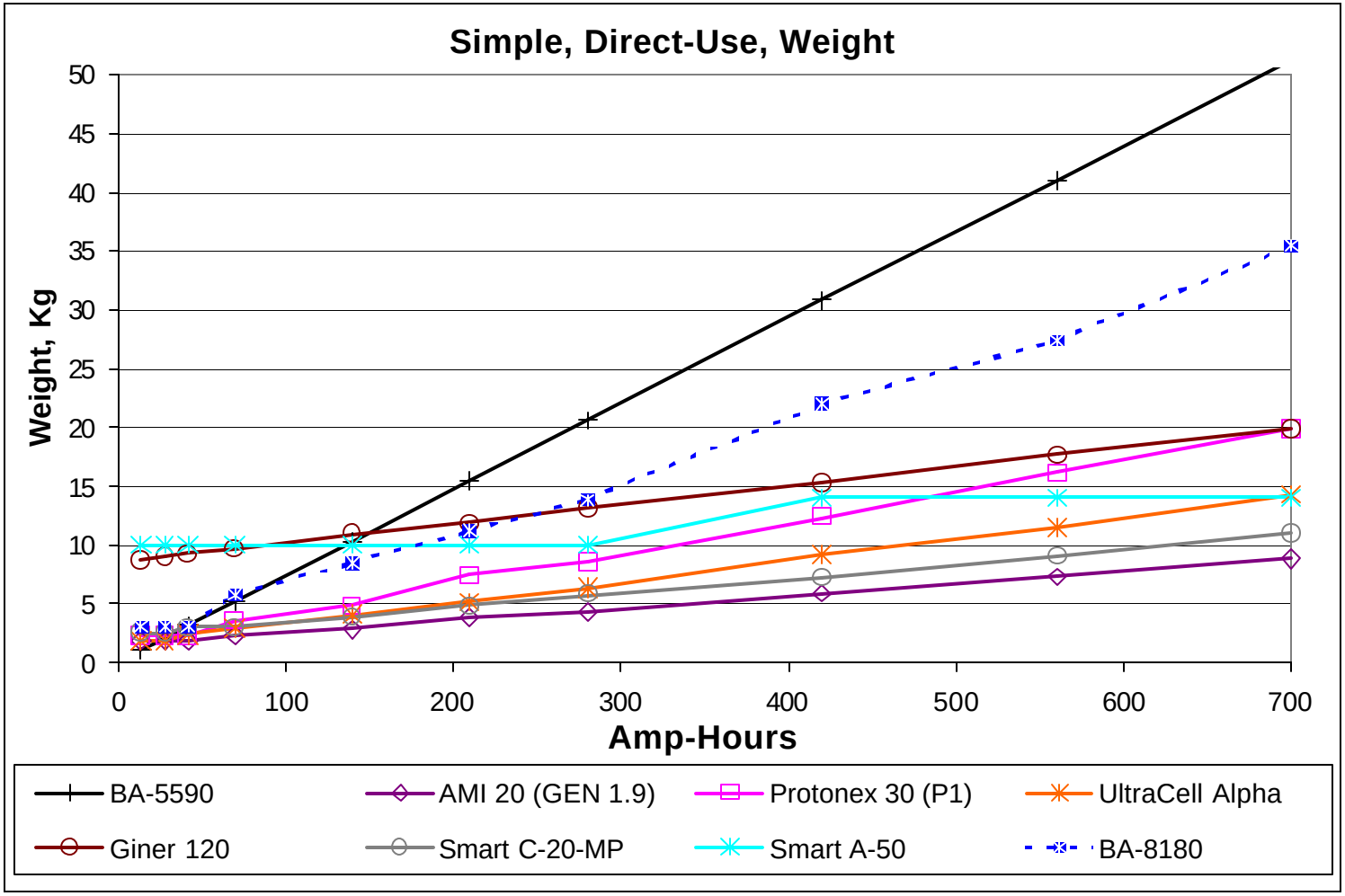
Manufacturer	Storage T/H (C, %RH)	Operating T/H (C, %RH)	Operating Altitude (Kft)
BA 5590 (Brentronix)	-30 to 55 --	-25 to 55 --	>15K
BA 8180/U (AROTECH)	TBD	-20 to 60 --	TBD
BB 2590 (Brentronix)	-20 to 55	-20 to 55	>15K
SFC 20 C20-MP	1 to 55 5 to 100	1 to 40 0 to 100	7K
SFC 50 A50	1 to 55 5 to 100	-20 to 40 0 to 100	10K
AMI 20 Generation 1.9	-40 to 55 TBD	-20 to 50 TBD	15K
Protonex 30 (DUS&T P1)	0 to 50 0 to 100	-10 to 50 0 to 100	10K
UltraCell 45A (Alpha Prototype)	TBD to 49 0 to 100	TBD to 49 0 to 100	TBD
Giner 120 (GES Prototype)	TBD	TBD	TBD

ALL Data Provided by Mfg/Spec Sheet

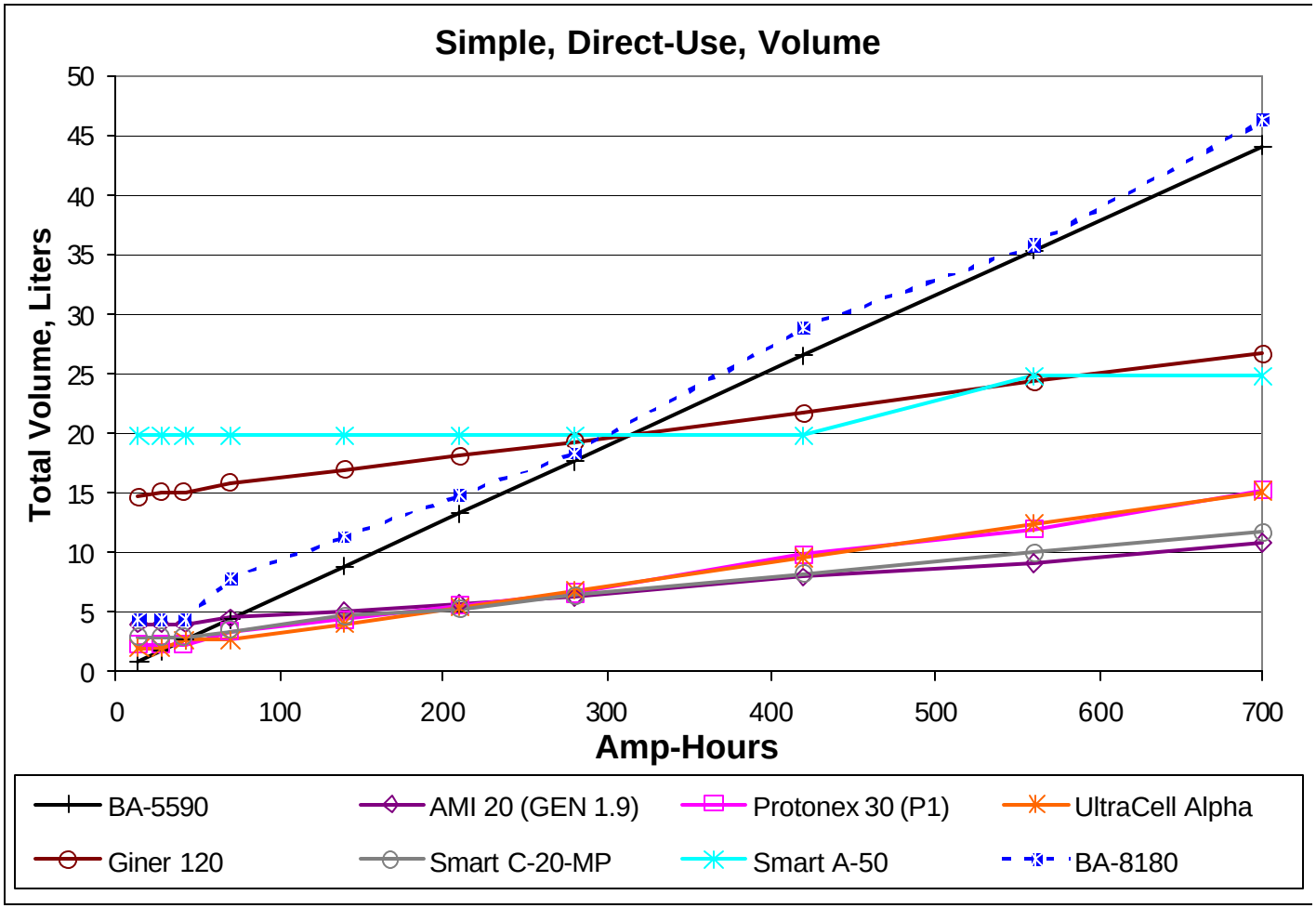
Simple Direct-Use Assumptions

- **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



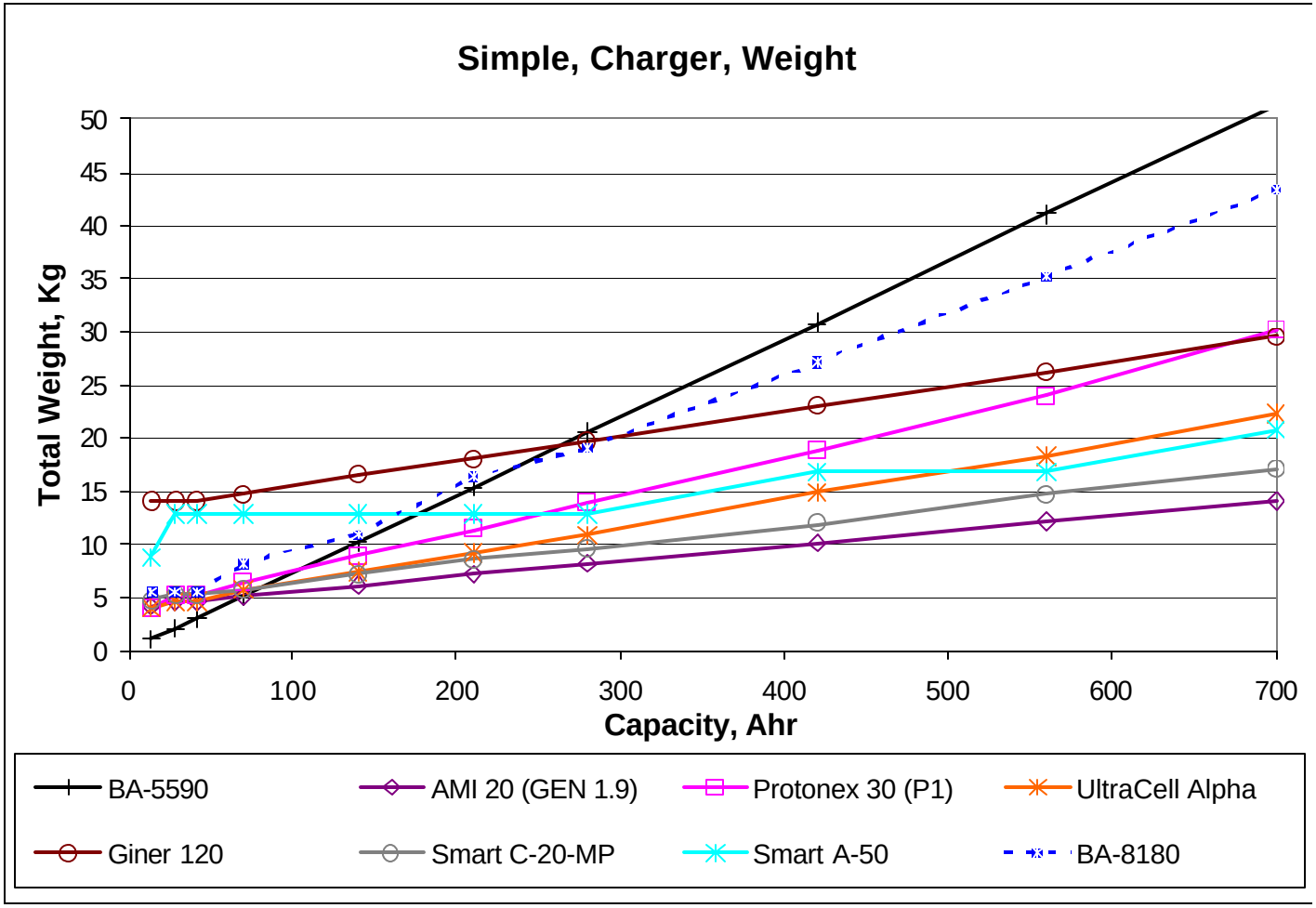
Simple Direct-Use Volumetric Comparison



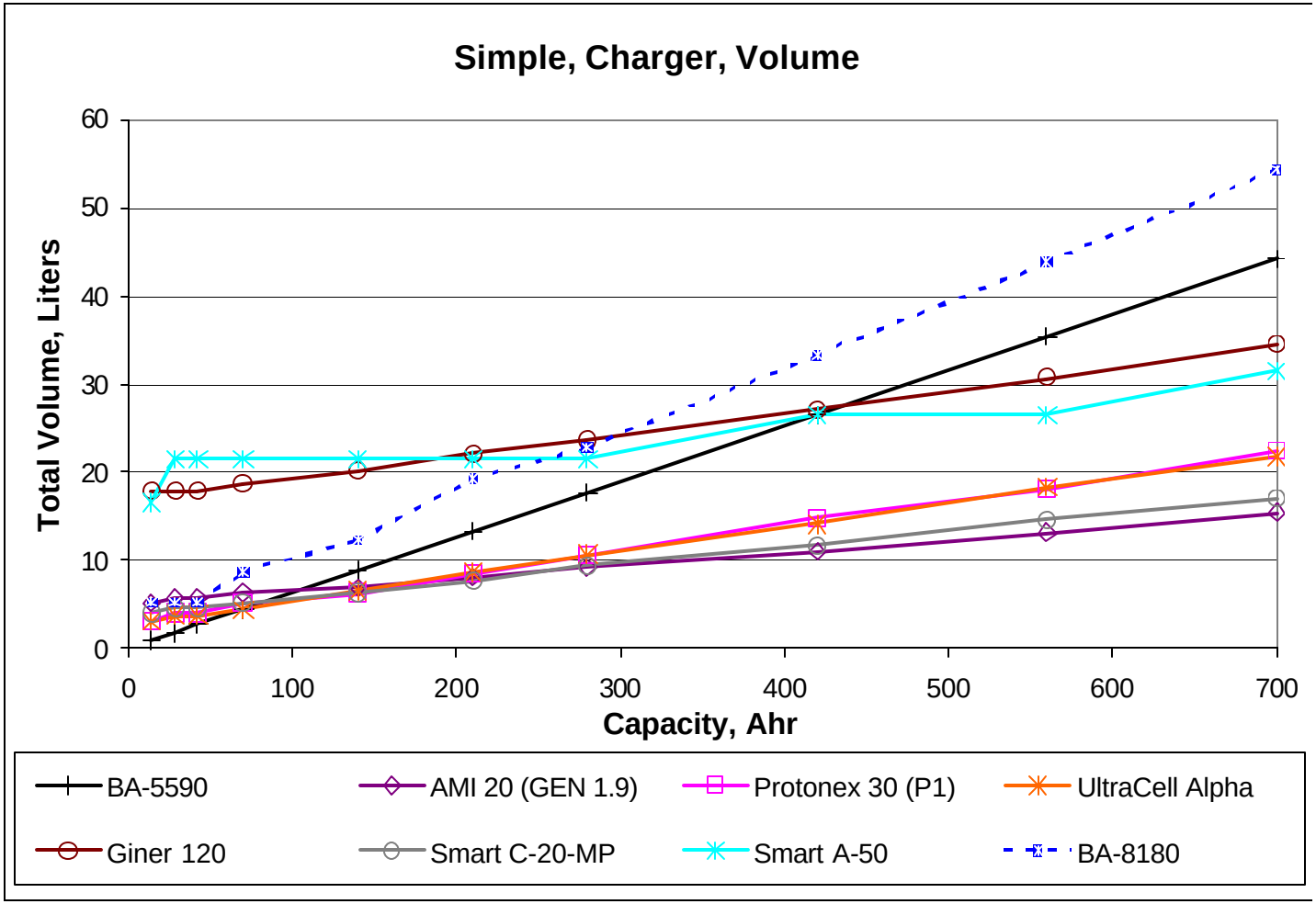
Simple Charger Assumptions

- **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



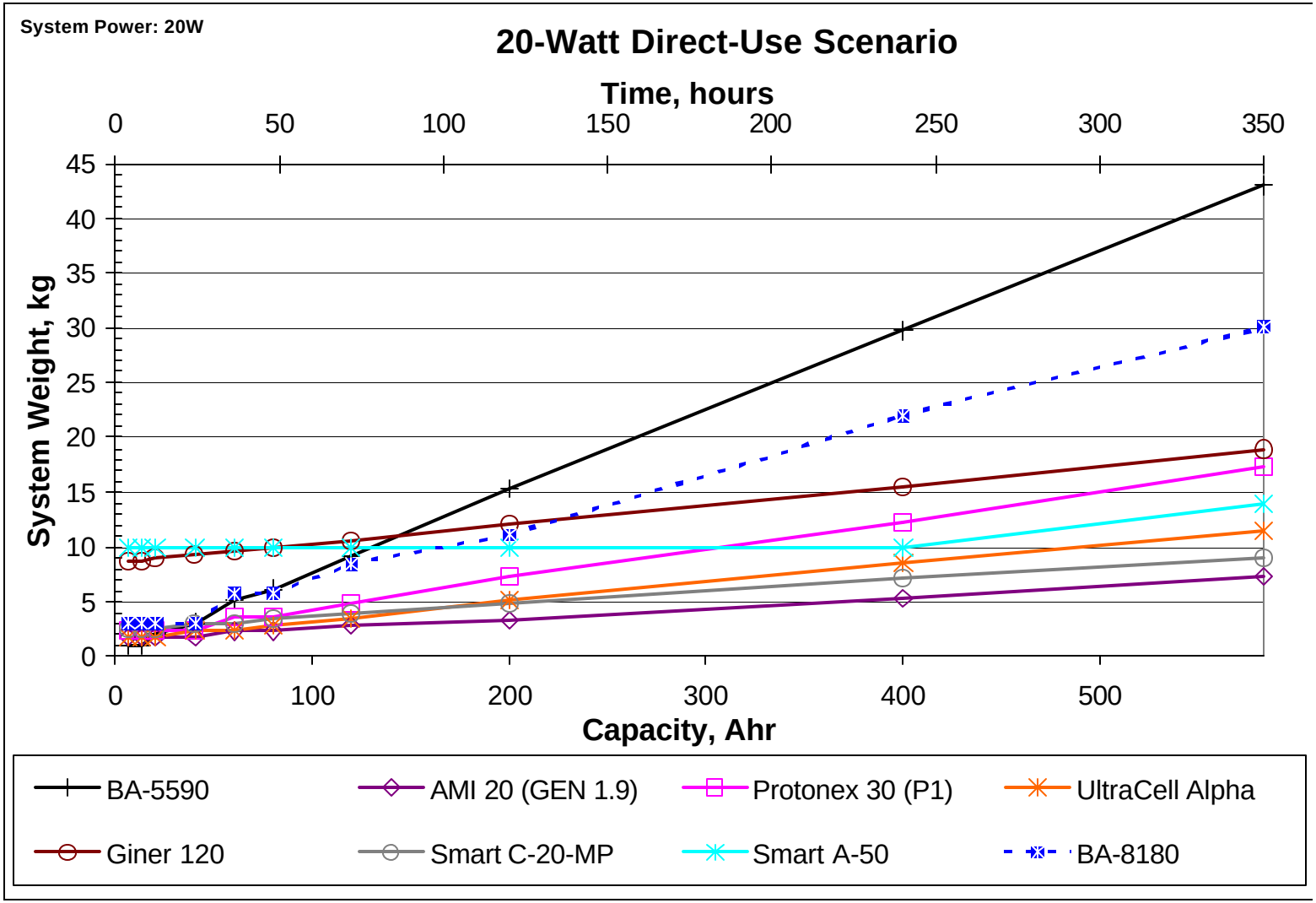
Simple Charger Volumetric Comparison



Primary Scenario Assumptions

- **Primary 12V 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+
      - Max battery weight ~50-100kg

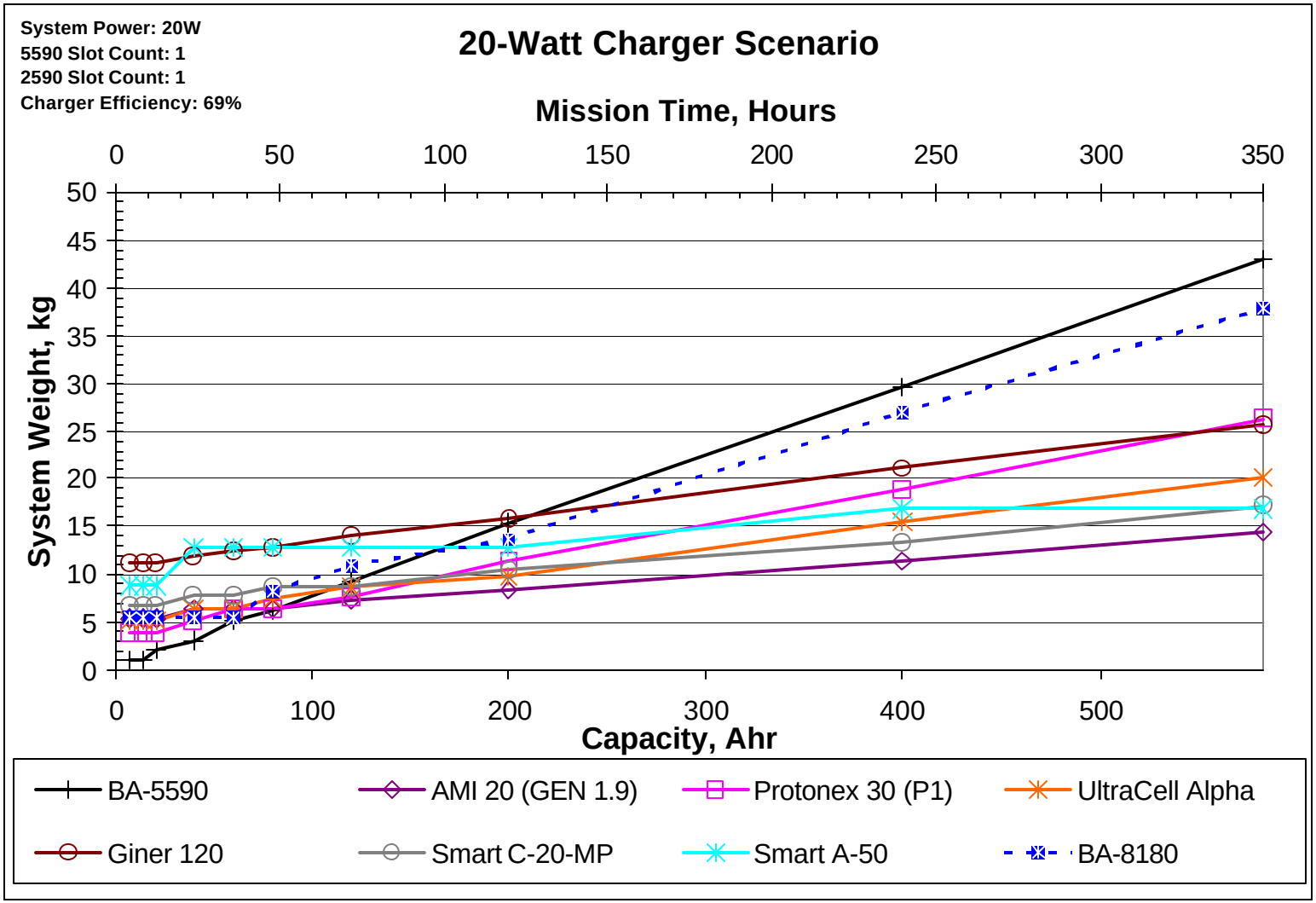
20W Direct-Use Scenario



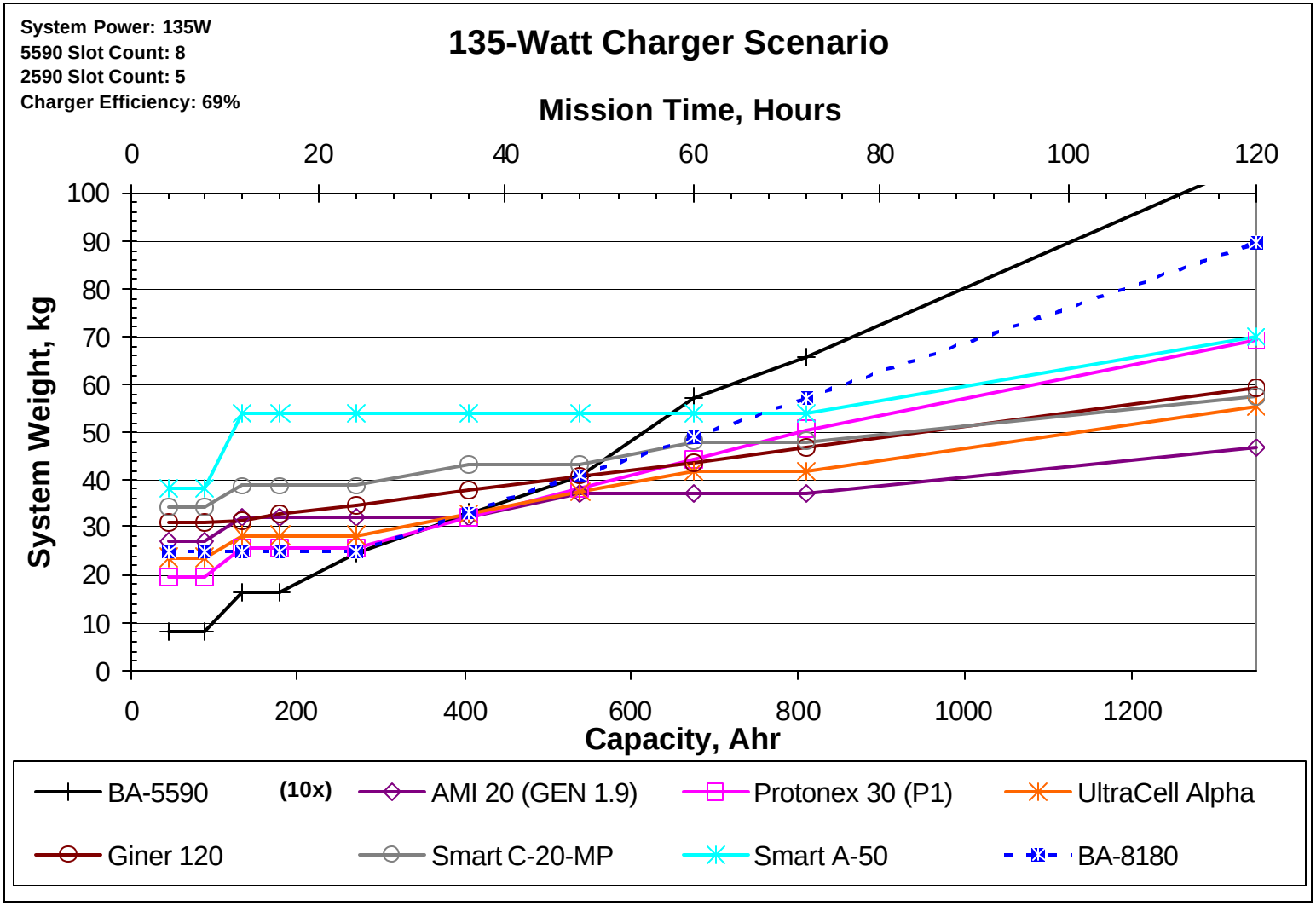
Charger Scenario Assumptions

- **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+
      - Max battery weight ~50-100kg

20W Charger Scenario



135W Charger Scenario



Technology Pro's & Con's

- **Signatures**
  - Exhaust 40 - 65C
  - 40- <65 dba
- **Orientation**
  - Upright +/- 30 - 45 Deg
- **Hybridization**
  - Weight/Volume Tradeoffs
- **Fuel Logistics**
  - Commodity
  - Logistic Fuel
- **Cold Start**
  - 0 –15 Minutes
- **TRL's**
  - 100-3000 Hr

Conclusions

- **Significant Gravimetric/Volumetric Potential With Fuel Cells**
- **Assorted Data (Actual Test, Provided, Projected) Clouds Projections Actual Performance Data at Specific Power Level Will Improve Quality of Projections**
- **System Maturity Must Also be Considered**
- **Hybridization Options Require Guidance**
- **Consider Bulk Fuel as Commodity for Future Comparison/Projections**
- **Each Technology Has An Application**

Recommendations

- **Regenerate Projections With Actual Performance Data At Power Levels**
- **Identify System Charge Circuit & Power Management Requirements**
- **Continue to Enhance Reliability & Durability**