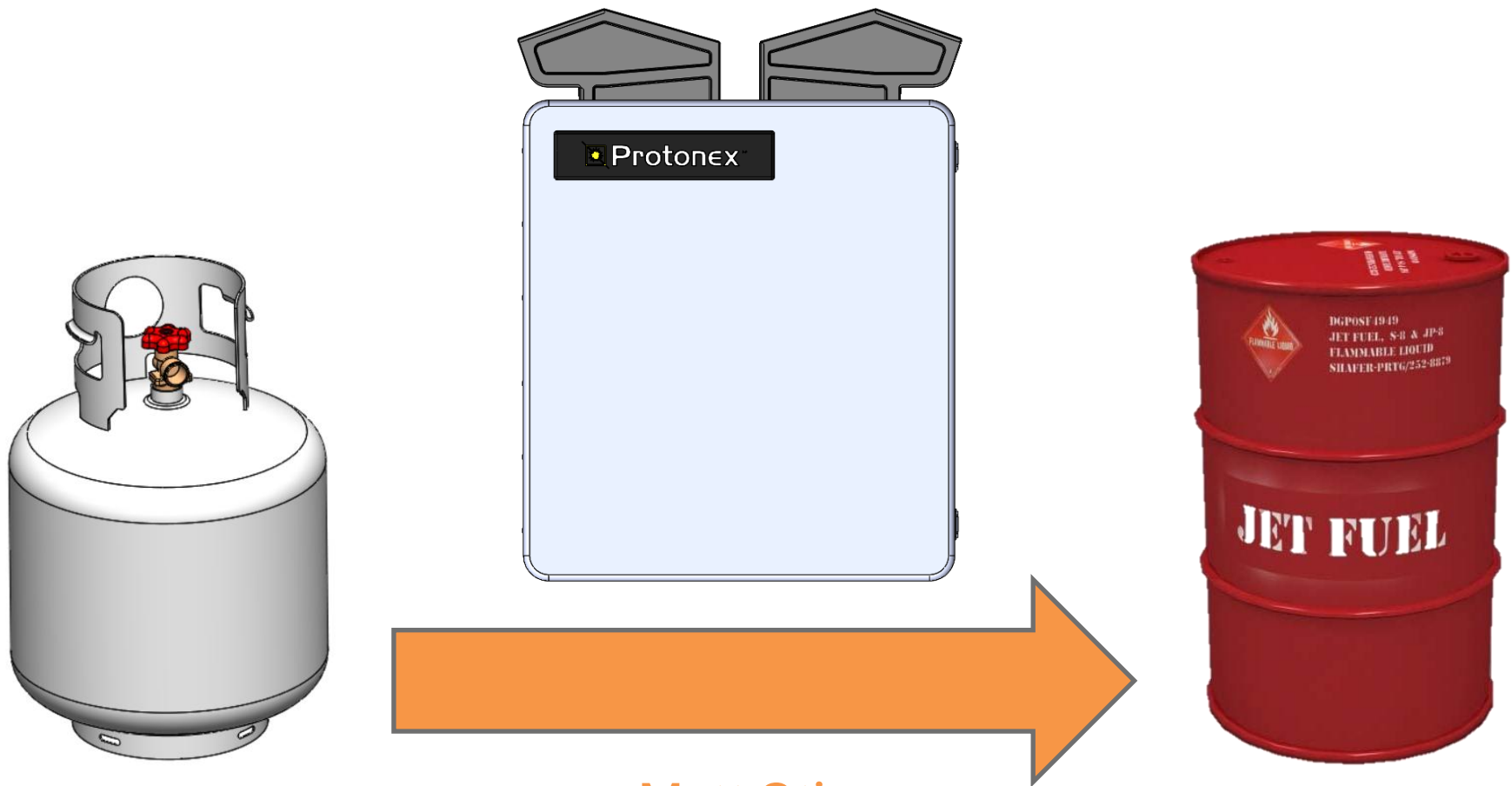


In-Field Fuel Consumption Reduction: Solar, Battery, Fuel Cell Hybrid Power System



Matt Otis
May 2, 2017

Contents

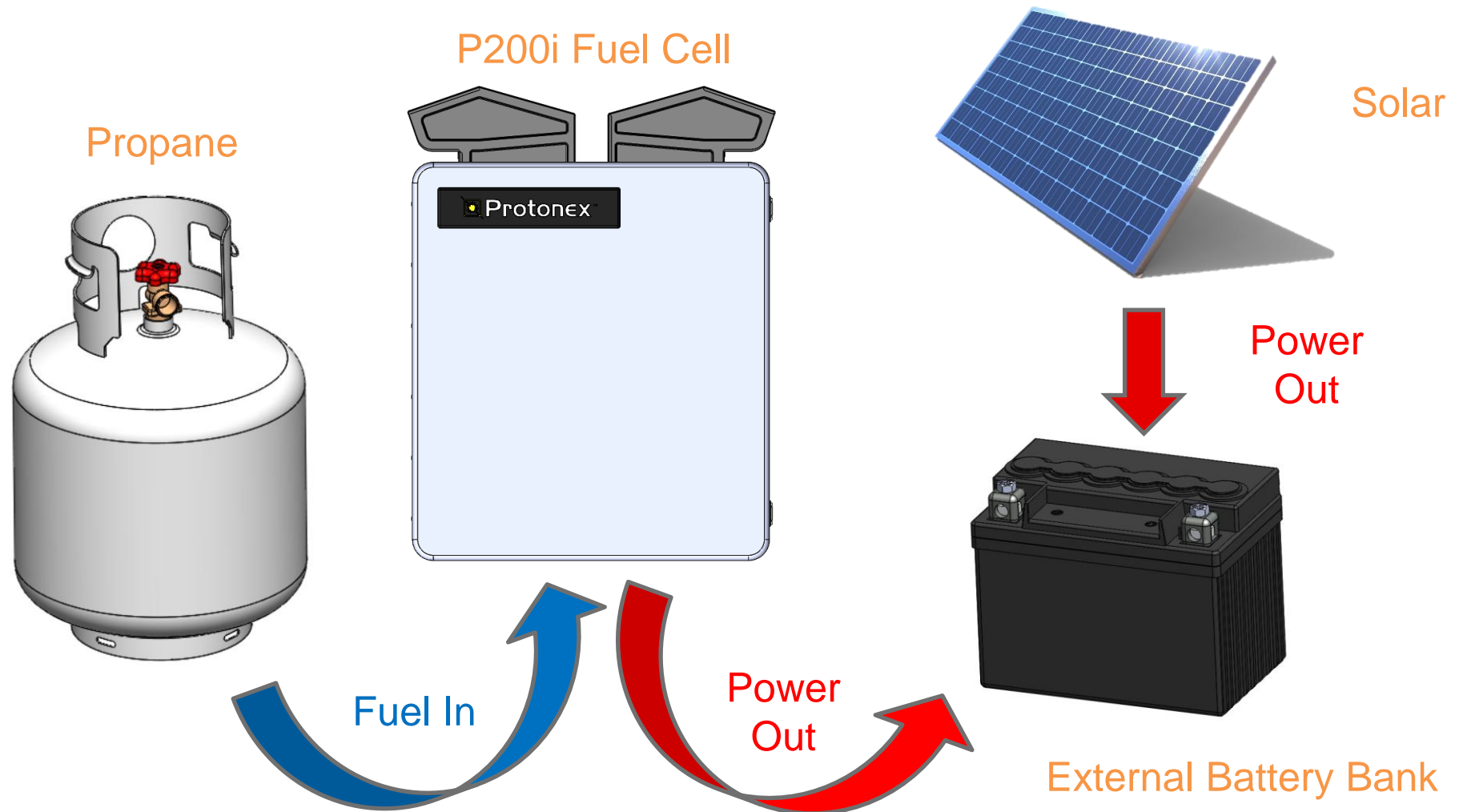


- **P200i – Current commercial SOFC product**
 - Overview
 - Core Technology
 - Specifications
 - Component Diagram
 - Durability
 - Capabilities
 - Beta Trials
 - Case Study
 - Typical Operation
- **Defense Product Development Path**
 - Defense Comparison
 - JP-8 Conversion
 - Solution
 - Applications
- **Summary**

P200i Overview



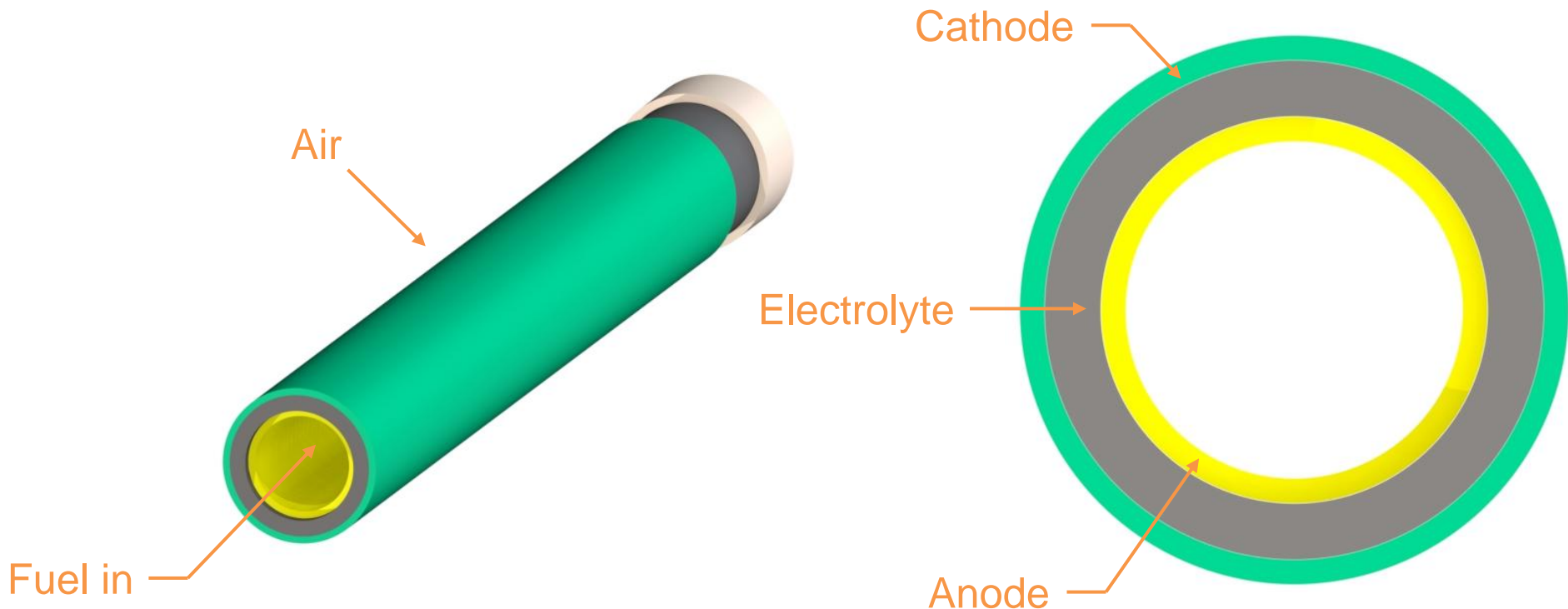
The P200i is a small, lightweight fuel cell system that utilizes commercially available LPG (Propane) to monitor and tend an external battery bank to power remote electrical equipment.



Core Technology: Solid Oxide Fuel Cells (SOFCs)



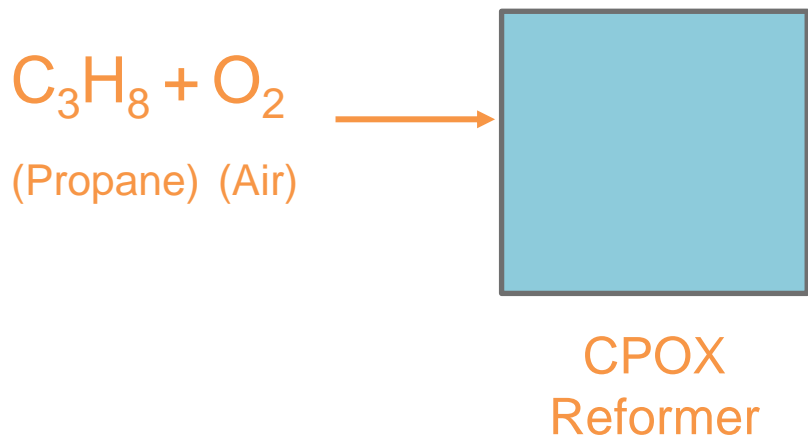
- Robust ceramic electrolyte
- Very high operating temperatures ($\sim 700^{\circ}\text{C}$)
- High temperatures allow for onboard reforming of hydrocarbon fuels.



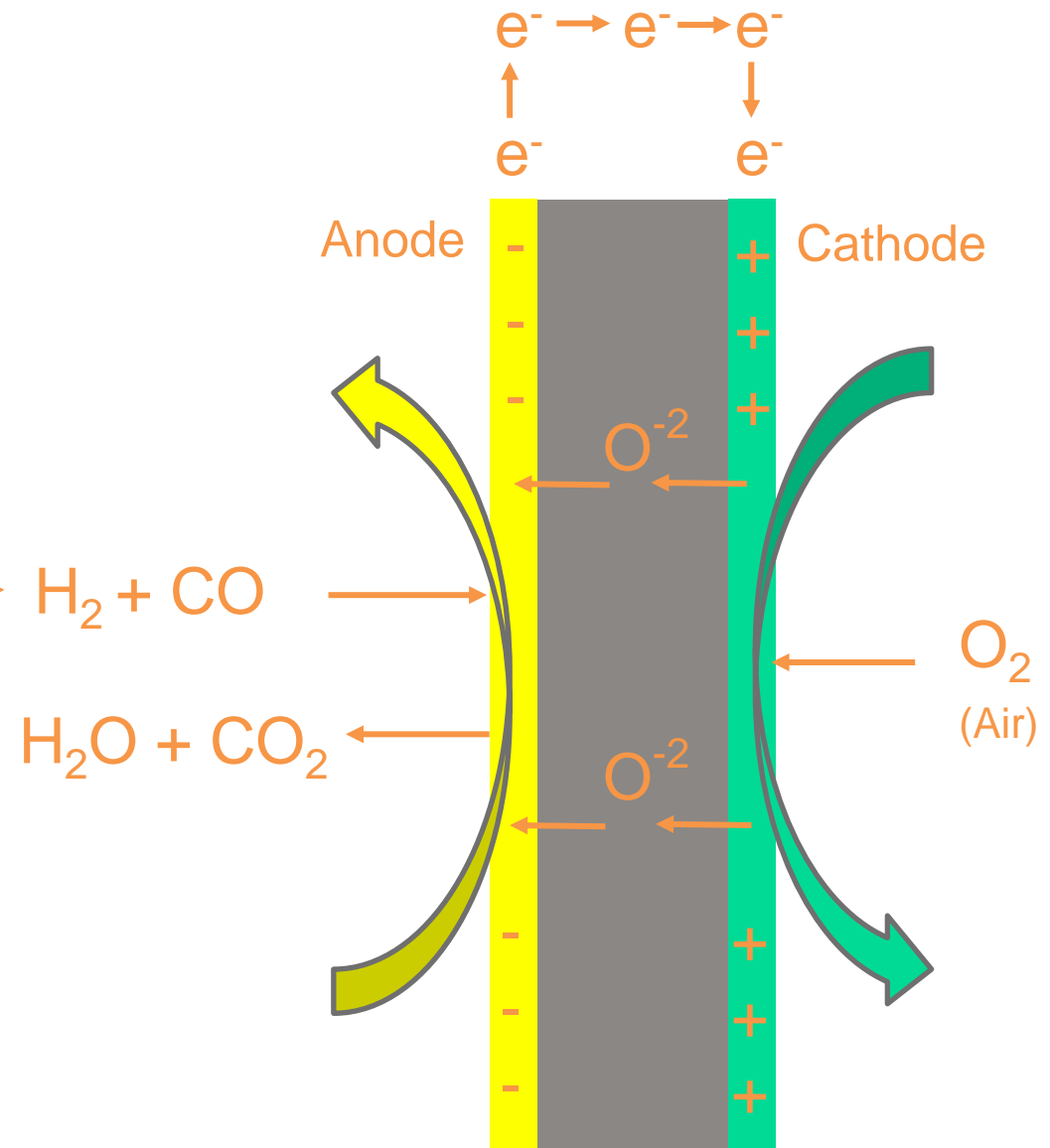
Core Technology: Fuel Processing



CPOX Reaction



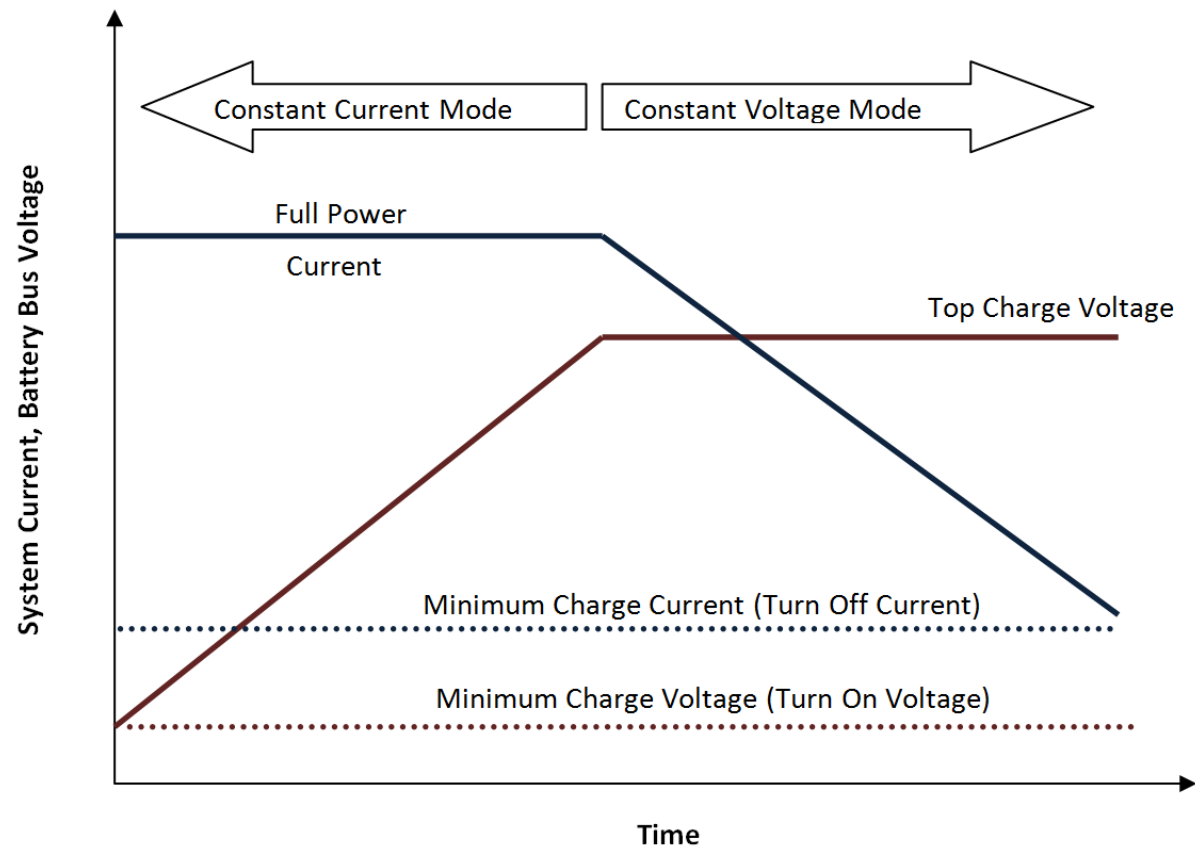
SOFC Reaction



P200i Operation



- Preset “turn on voltage” and “turn off voltage”
- Powers on at “turn on voltage”
- 15 minute heat up
- Charges battery until “turn off voltage” reached
- 20 minute cool down



P200i Specifications



FUEL: Liquefied Petroleum Gas (LPG per GPA Standard 2140-97)



Efficiency: 17% (4-5hrs run time per lb. of propane)



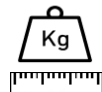
Power (net): Initial 200W with turndown capability to 50W.



Power Type: Designed to work with 12 - 48 VDC systems.



Maintenance Free: No seasonal maintenance required



Size / Weight: 60cm x 40cm x 20cm / 20kg



Operational Environment: -30°C to +55°C, 4000m altitude, IP54



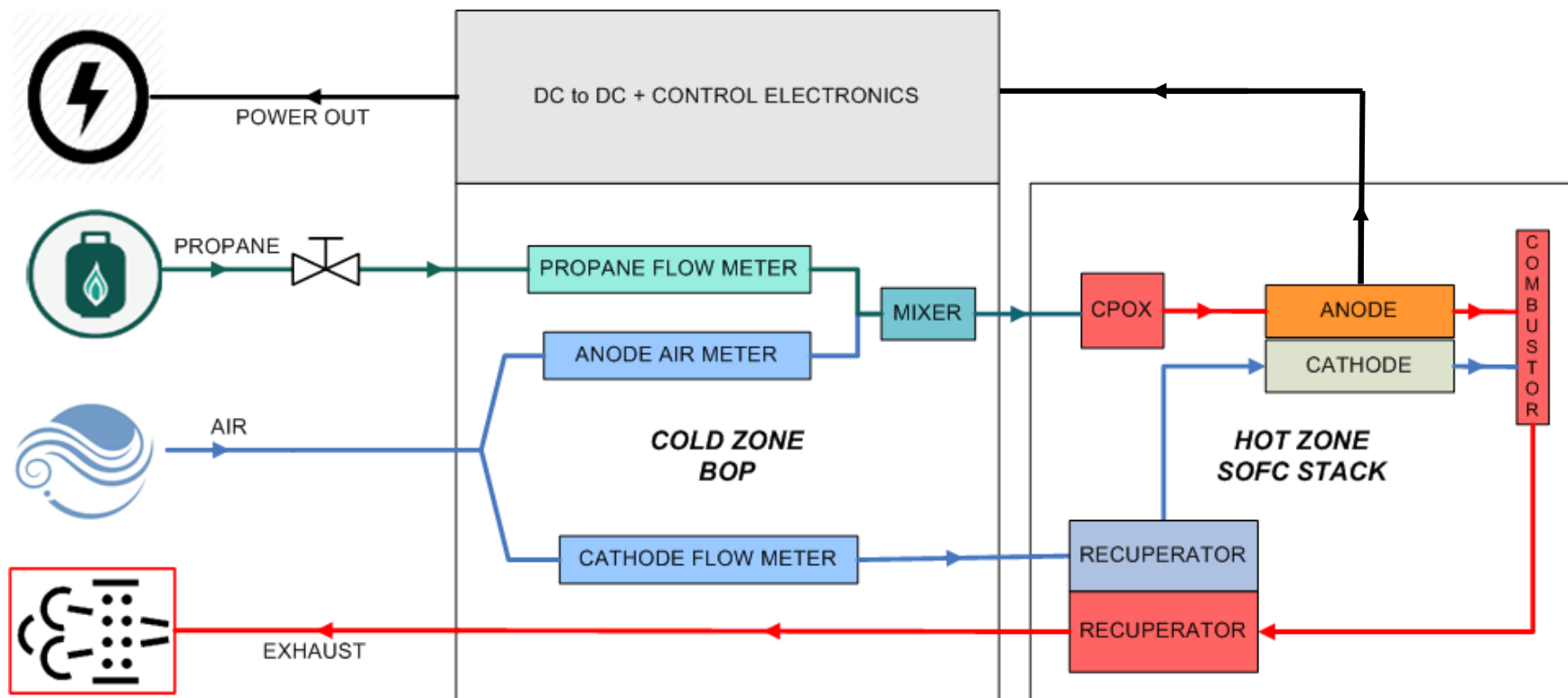
Remote Communication: TCP/IP interface



Safety: Onboard CO and Propane leak detection

P200i Component Diagram

SOFC SYSTEM BLOCK DIAGRAM



P200i Durability



- Ruggedized design for extreme environments
- Survived vibration and 4ft drop tests
- Can operate at -30°C

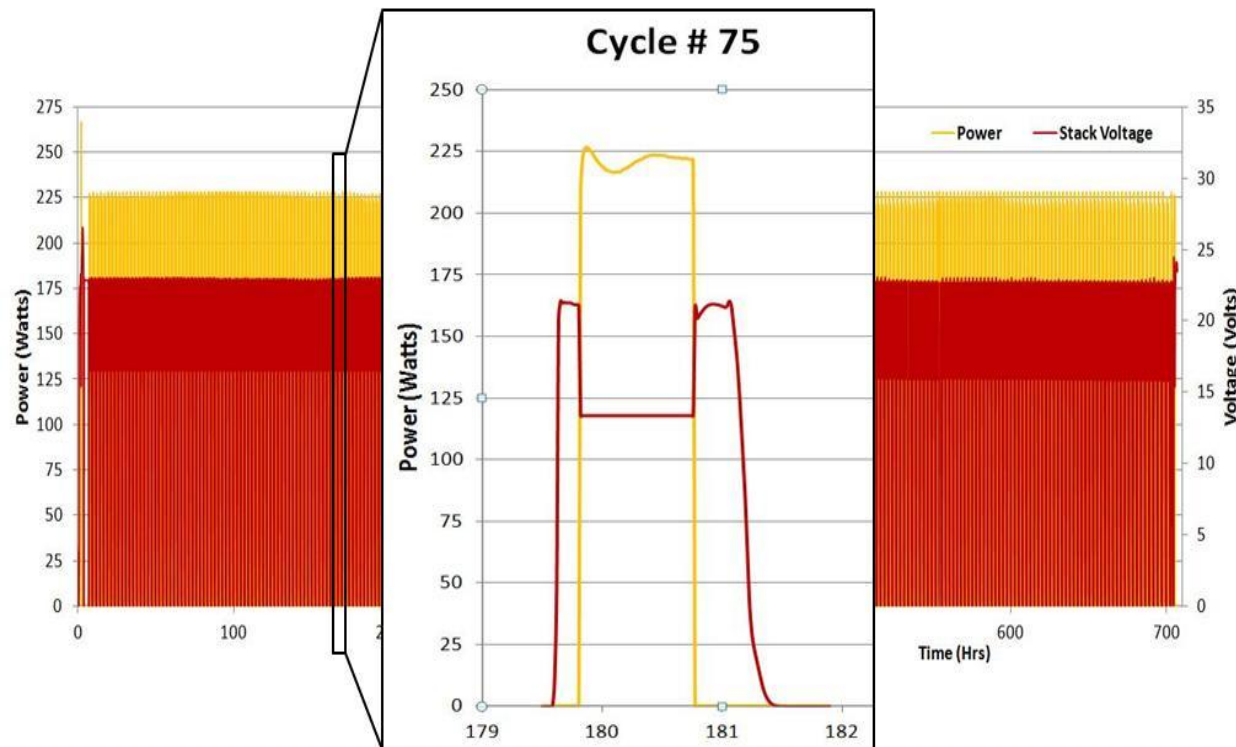


*Alaska Cell Repeater – Summer
and Winter Pictures*

P200i Capabilities



- Unlike other SOFC products – the P200i can turn on and off easily.
- Allows for less fuel consumption and ultimately higher lifetime efficiencies
- Lab testing has shown P200i hot zone life times can be in excess 6000 hours



Cycle test showing 250+ cycles

Beta Trials



- **Currently in Closed Beta Trials with Multiple Customers/ Markets**
 - Remote Sensor – Wind
 - Remote Sensor – Natural Gas Well
 - Telecom/ Cell Repeater Stations
 - Traffic Cameras
 - Railroad Signal and Sensors

Unrestricted Availability in Late 2017

Case Study: Rocky Mountain Location



- **Weather station with road condition monitoring**
 - No need for an additional power source during the spring, summer, and fall
 - Winter of 2016 – prior to P200i installation had an uptime of only **35%**
 - Winter of 2017 – over **90%** uptime after the P200i installation

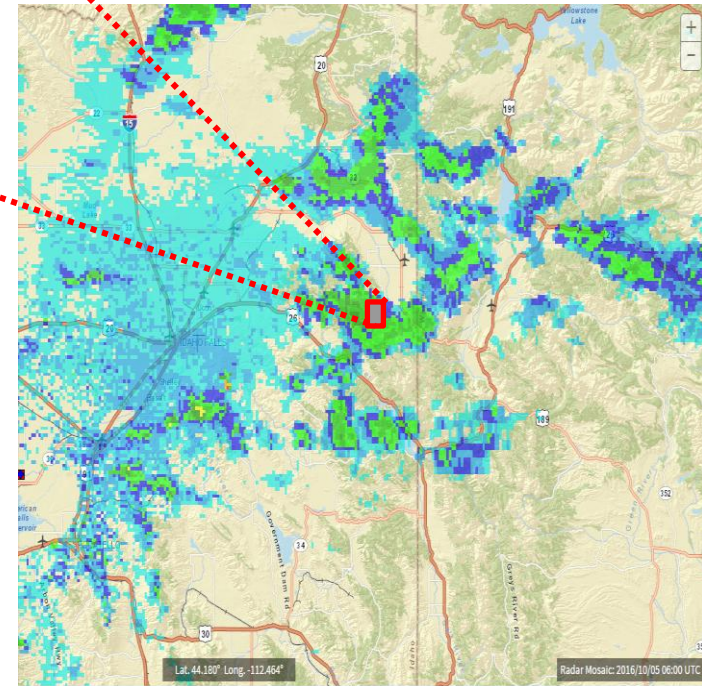


P200i hybridized installation

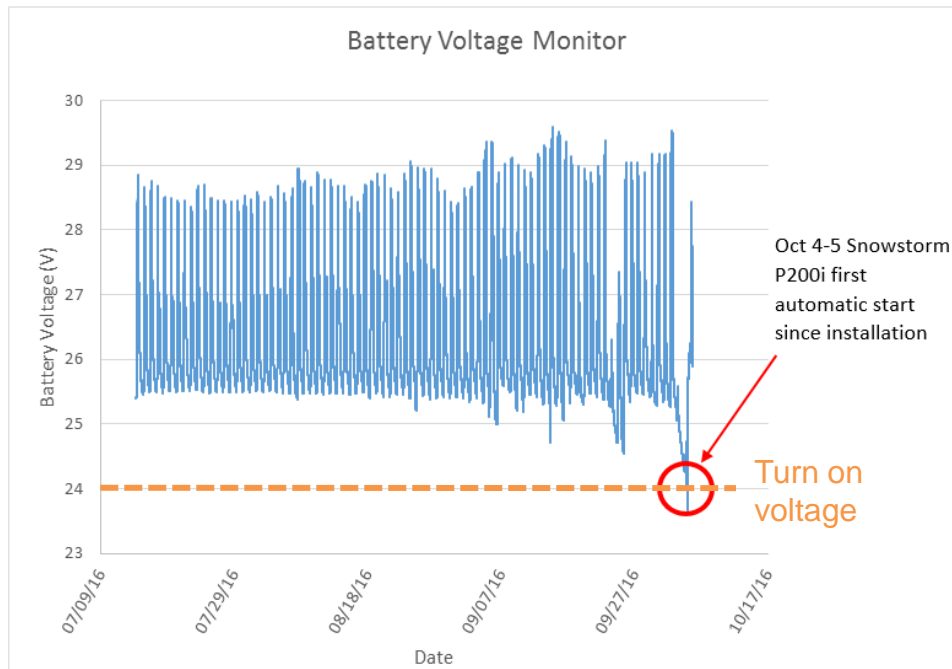
Typical Operation



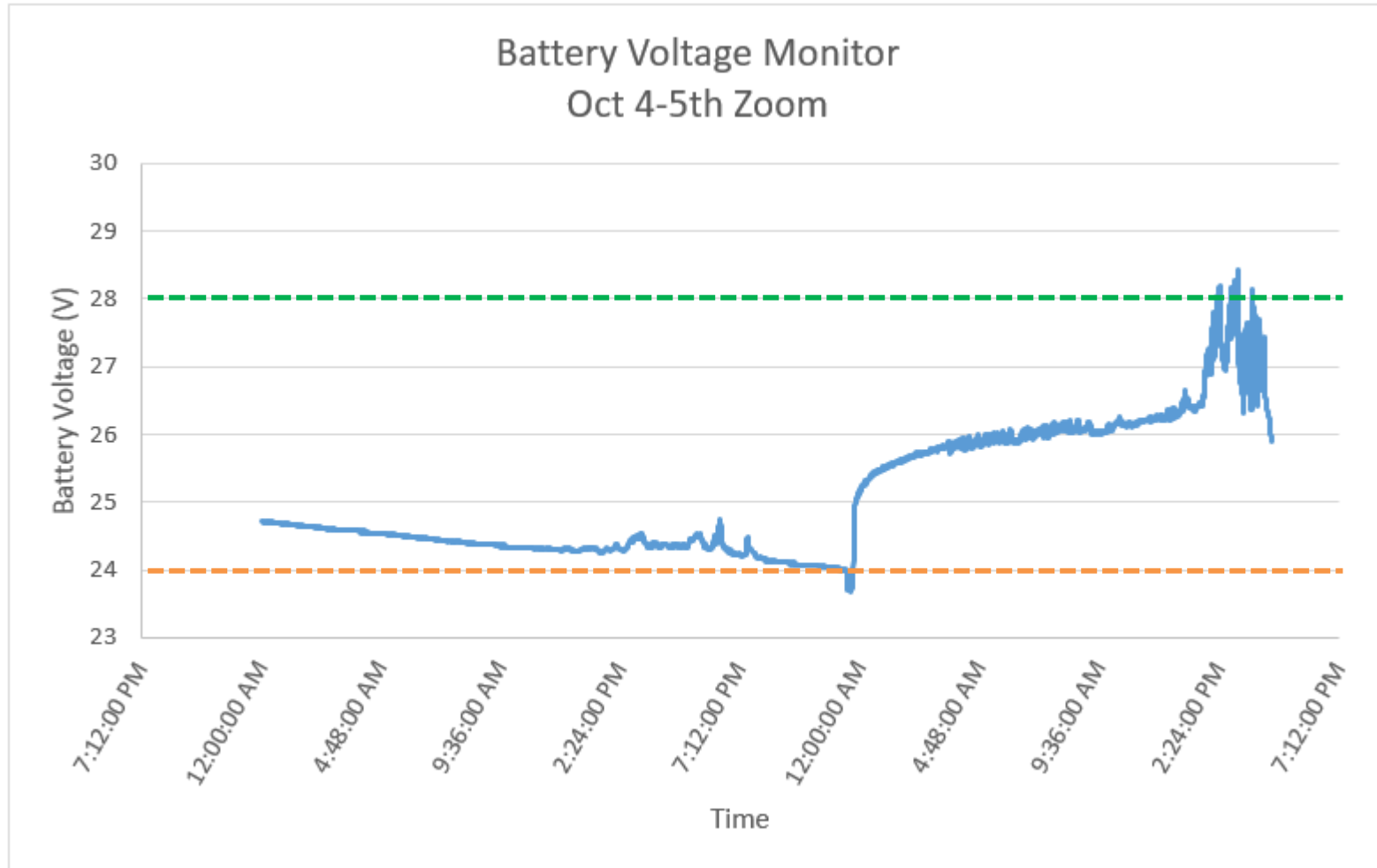
Remote Rocky Mountain weather station



Doppler Oct 5, 2016



Typical Operation



Turn off voltage

Turn on voltage

Remote DoD Power Comparison



JP-8 Military
Generator



- Excessively noisy
- Difficult to hybridized with batteries or solar (AC based)
- Inefficient at low power
- Fuel: JP-8 – readily available

Protonex M300 Methanol
Fuel Cell System

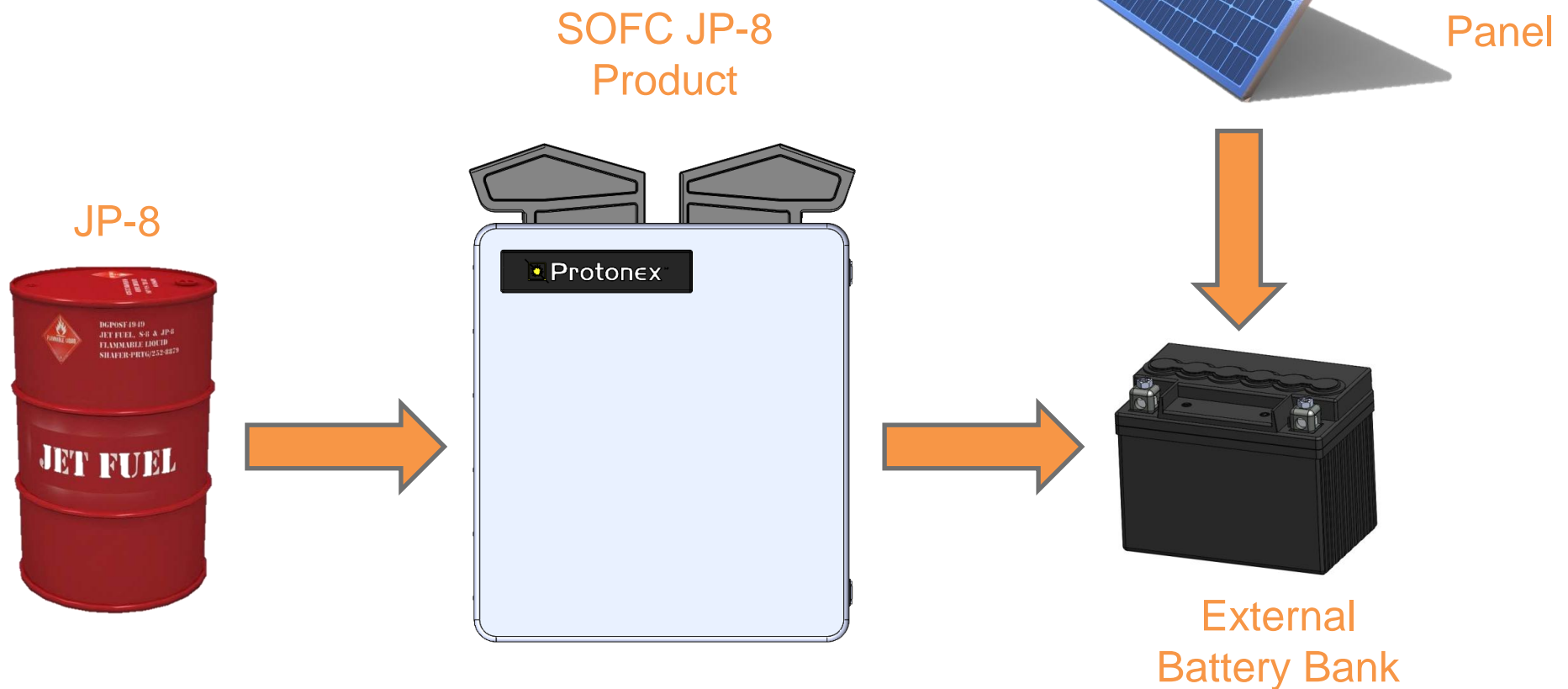


- Quiet operation
- Easily coupled with solar for reduced fuel consumption
- High Efficiency – Good turndown capabilities
- Fuel: Methanol – not a common DoD fuel

Military/Defense Solution



- Solar/Battery/Fuel Cell hybrid to replace traditional 24/7 low power generators at FOBs or remote DoD sites
- **Maintenance free – 100% uptime solution**
- **Dramatically reduce JP-8 consumption**



JP-8 Fuel Processing



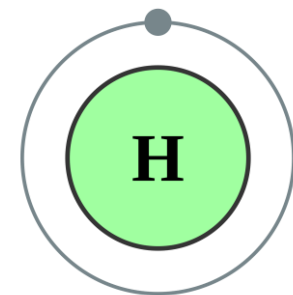
- Possible to modify the P200i to use JP-8 instead of propane
- Successful TRL-5 demonstration with desulfurized JP-8 has been performed by Protonex
- Several vendors have mature JP-8/desulfurization technologies tested at to higher TRLs



JP-8



CPOX
Reformer



Hydrogen

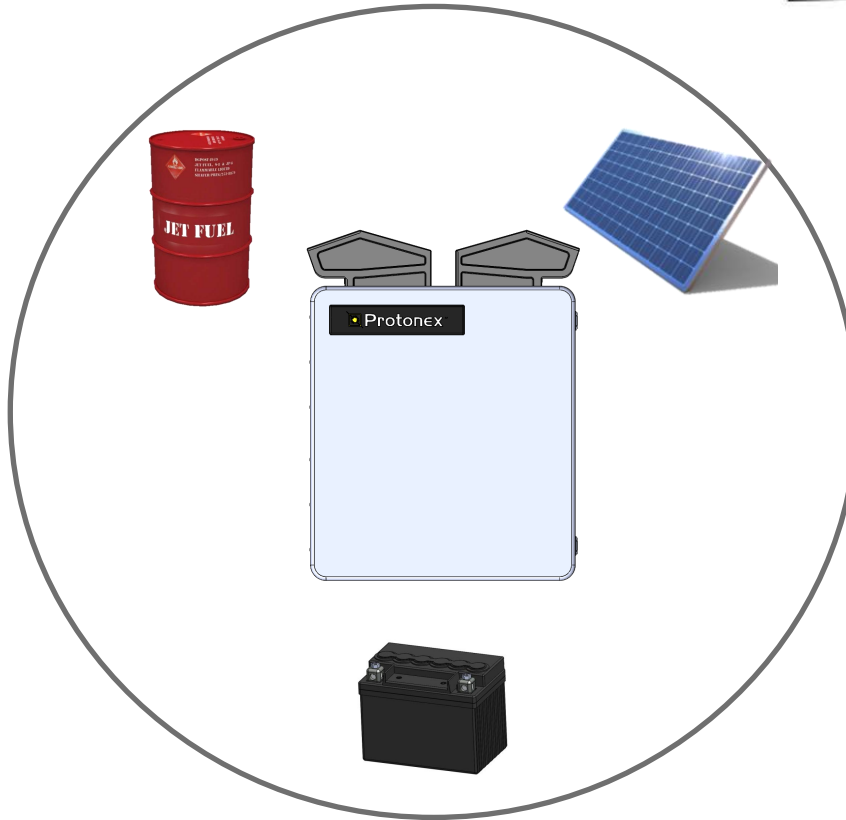
Military/Defense Applications



Security Cameras



UAV/Drone Recharging Stations



Hybridized JP-8 SOFC/Solar Package

Remote Sensors/
Communication Relays



Weather Stations



Summary



- SOFCs have matured in recent years
- Triple hybrid systems (P200i/solar/battery) are gaining traction in the commercial remote power sector
- Opens up possibilities in military applications with similar remote power needs
- The technology to process JP-8 to be used in SOFC exists but has not been implemented yet

Thank You.
Questions?