RDECOM

US ARMY NATICK SOLDIER RD&E CENTER

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Greening the U.S. Army

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June 26, 2008

Outline

- **Greening the U.S. Army**

Why Green the Army?

Executive Orders

Financial Benefit

Environmental Benefit

What is the Army doing to make it Green?

- Zero Footprint Camp
- Waste to Energy Converters
- Photovoltaics
- Fiberboard
- Shelters

Natick Soldier RD&E Center (NSRDEC)

- **Mission Areas**
  - Individual Protection
  - Collective Protection
  - Airdrop / Aerial Delivery
  - DoD Combat Feeding
  - Supporting Science and Technology
  - Warrior Systems Technology Integration

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DoD Combat Feeding

- **Combat Rations**
- **Field Food Service Equipment**
- **Combat Feeding Systems**

- **S&T Thrusts Areas:**
  - Energy & Equipment
  - Food Safety / Biosensors
  - Novel Preservation & Stabilization
  - Novel Nutrient Delivery
  - Revolutionary Packaging
  - Logistics

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Base Camp Waste Disposal

The unfortunate reality at base camps…

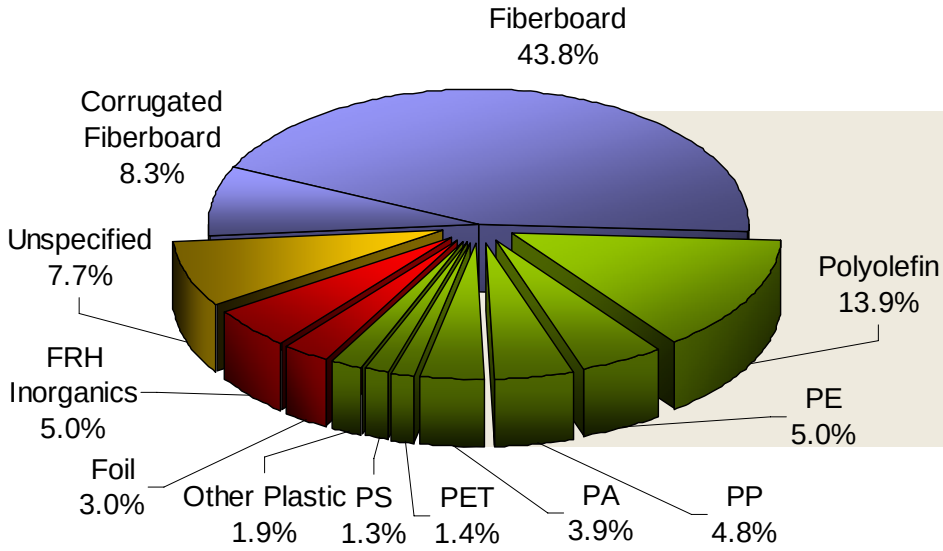
Open burn box with no emissions control

Example:
Solid Waste Disposal at ASG Eagle Base (Bosnia)

Mounds of leftover partially burned trash

<u>Energy wasted</u>!

Operational Ration Packaging



Meal Ready-To-Eat Packaging

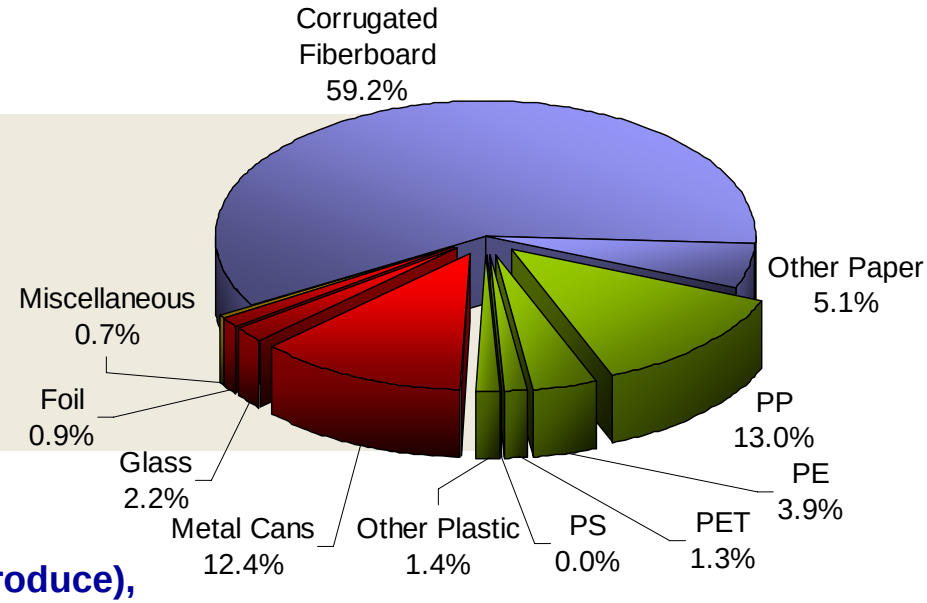
(0.61 lb/man-meal)

- Using available data to provide best estimate of component materials
- Many materials are bound in laminates and therefore inseparable

Unitized Group Ration Packaging

(0.49 lb/man-meal)

- Data represents an average of Dinner Menu 2 and Menu 7, and may not be representative of all UGR menus



Does not address materials associated with enhancements (e.g., milk, yogurt, and fresh produce), beverage bottles, and other items not included in these operational rations

Zero Footprint Camp (ZFC) Concept

Mobile Waste to Energy Conversion

Waste Water Processing & Reutilization

ZFC

"Designer Trash"

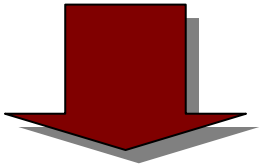
Composting

Kitchen Sanitation System

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Overview

- ☆ **Reduce Logistics Footprint ⇨ Save Dollars**
- ☆ **Reduce Safety & Health Risk ⇨ Optimize Personnel Availability**
- ☆ **Minimize Environmental Risk ⇨ "Zero" Footprint**



"Waste" isn't Waste ⇨ It's a Resource

The ZFC Impact

Force Protection

Intelligence: Eliminates Enemy Intelligence Source
Physical Security: Eliminates need for Civilian Access
Health: Reduced Death Rates

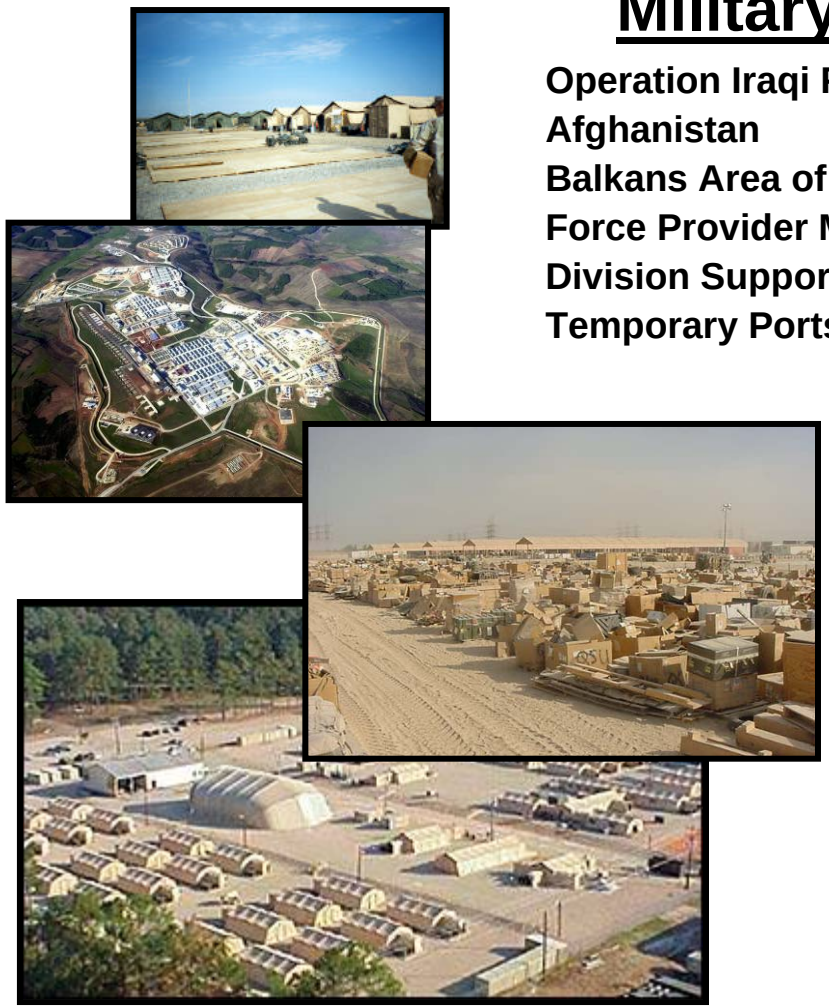
Environment

Eliminates Compliance & Clean-Up
Provides Enriched Soil for Soldier or Host Nation Use
Reduce Greenhouse Gas Emissions
Zero Footprint

Logistics & Sustainment

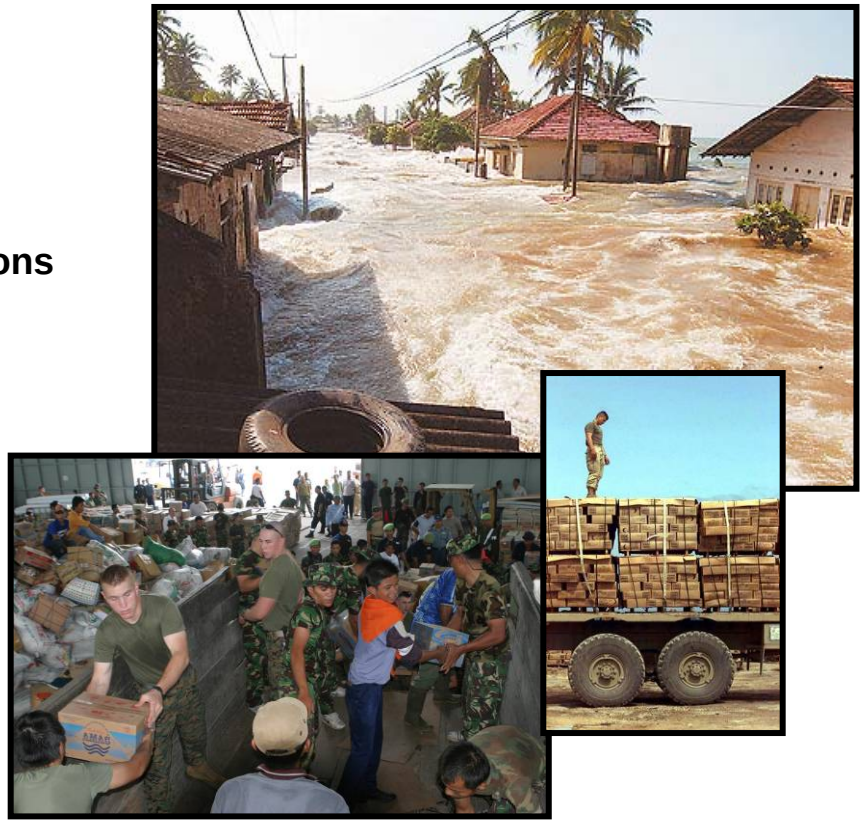
Reallocation of Engineer Assets
Water Requirements Reduced by up to 80%
Power Generation Augmented by 30%
Diesel Fuel Requirements Reduced by 30%
Transportation:
- **Supply Convoys Reduced**
- **Waste Convoys Eliminated**

Potential Applications



Military

Operation Iraqi Freedom
Afghanistan
Balkans Area of Operations
Force Provider Modules
Division Support Areas
Temporary Ports



Civilian

Humanitarian Relief
Disaster Aid

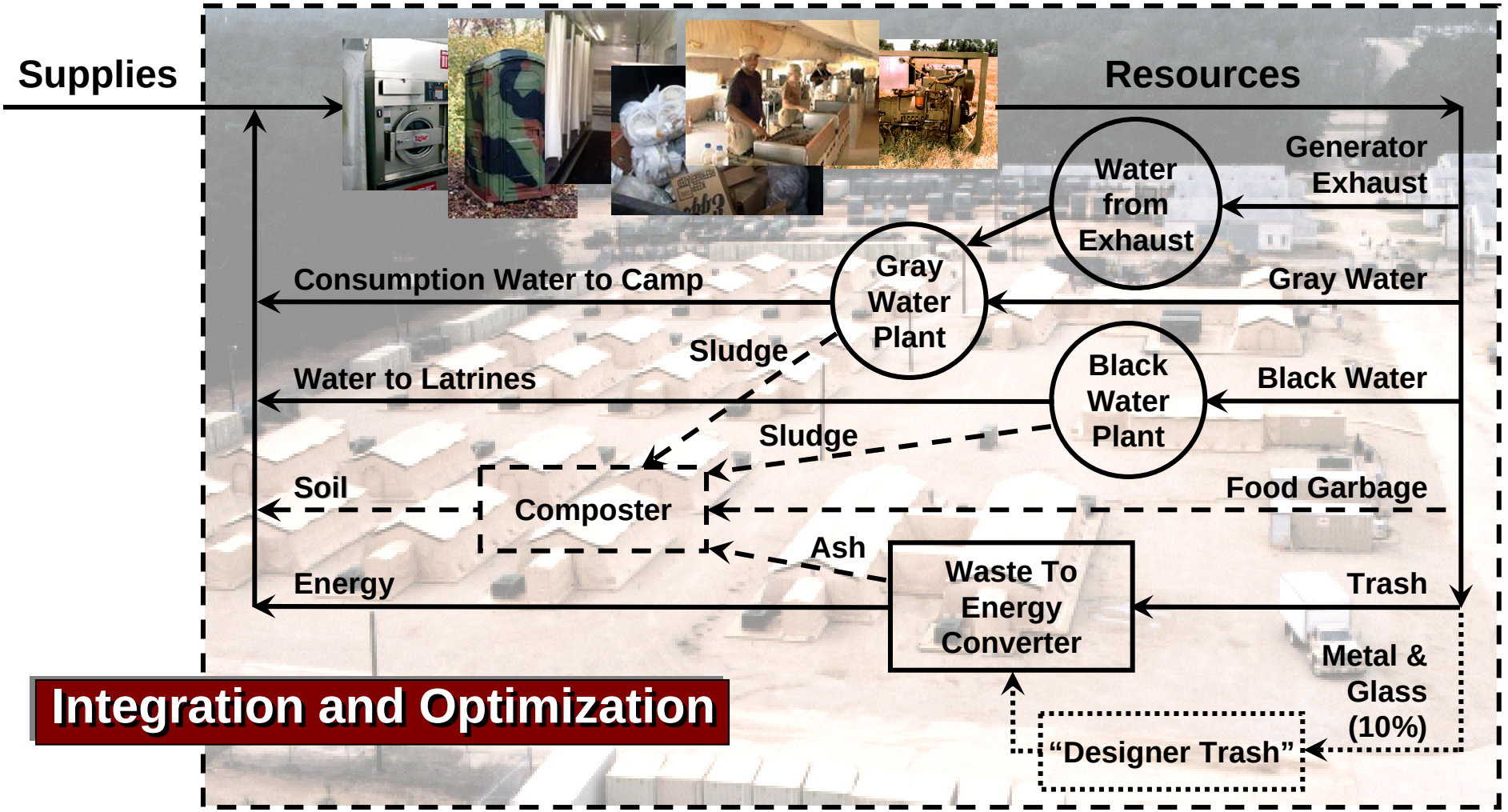
Current Approach

Supplies
- Food
- Water
- Fuel
- Personal Items

Waste
- Dirty Used Water
- Sewage
- Food Garbage
- Trash
- Exhaust

Managing the Waste

ZFC Integration:
"Thinking Back Inside the Box"



Integration and Optimization

ZFC-related Focus Areas

- **Energy Recovery & Storage Systems**
  - Photovoltaics
  - Fuel Cells
  - Advanced “Batteries”
  - Geothermal
- **Thermally efficient structures**
  - Tent/shelter liners
  - Protective covers
- **Energy efficient appliances**
  - LED lighting
  - Thermo electric

Waste To Energy Conversion

- **Several technologies available to eliminate solid waste**
  - Incineration
  - Gasification
  - Pyrolysis
  - Steam Reformation
- **Conversion to energy requires system engineering & configuration effort**
  - Boiler/turbine configuration
  - Synthetic gas conversion to fuel generator
- **Potential research areas**
  - Ash reutilization or elimination
  - Air emissions reutilization
  - Fuel cells as the energy source

WEC — Waste to Energy Converter

- **Objective:**
  - Develop and demonstrate technologies that treat solid waste as a resource, producing useful energy while minimizing field waste

- **Capability Provided:**
  - Onsite conversion of solid waste into electricity and high-quality heat for field-feeding and organizational equipment
  - Reduced logistics tail in terms of fuel consumed and trash backhauled

Waste Stream Data Comparison

	Army Field Feeding System (Fort Campbell, April 1995)	Force Provider Training Module (Fort Polk, June 2000)	AF Bare Base* (Derived from PSAB data)	ASG Eagle Base Camp (excluding wood)	ASG Eagle Base Camp (including wood)
Study Population	**210**	**164**	**1182**	**3700**	**3700**
Paper & Cardboard	**45%**	**38%**	**53%**	**49%**	**12%**
Plastic	**8%**	**12%**	**26%**	**34%**	**8%**
Food	**14%**	**40%**	**2%**	**4%**	**1%**
Misc	**12%**	**7%**	**10%**	**8%**	**2%**
Metal & Glass	**21%**	**3%**	**6%**	**5%**	**1%**
Wood	**–**	**–**	**3%**	**–**	**76%**
Per Capita (lbs/person/day)	**3.2**	**4.1**	**13.2**	**3.0**	**12.6**
Fuel Potential	**79%**	**97%**	**94%**	**95%**	**99%**

* This data is estimated, and the methodology used was not specified.

WEC Vision: A Paradigm Shift

TODAY:
Waste is a Liability

- **Waste disposal costs time & money**
  - – Expensive logistical burden
- **Reliance on host nation support is problematic**
  - – Overwhelm local capabilities
  - – Human health and environment
- **Waste footprint usable by the enemy**
  - – Signature
  - – Force protection

VISION:
Waste is Power

- **Paradigm shift**
  - – Waste less a liability, more a resource
- **Convert field waste into useful power and heat for field-feeding and organizational equipment**
- **Positive Impact**
  - – Reduced military waste footprint
  - – More self-sufficient forces
  - – Improved force protection

Energy Potential of Waste

90 lbs
mixed waste

has energy content equivalent to…

5 gal

…and more than 50% can be recovered

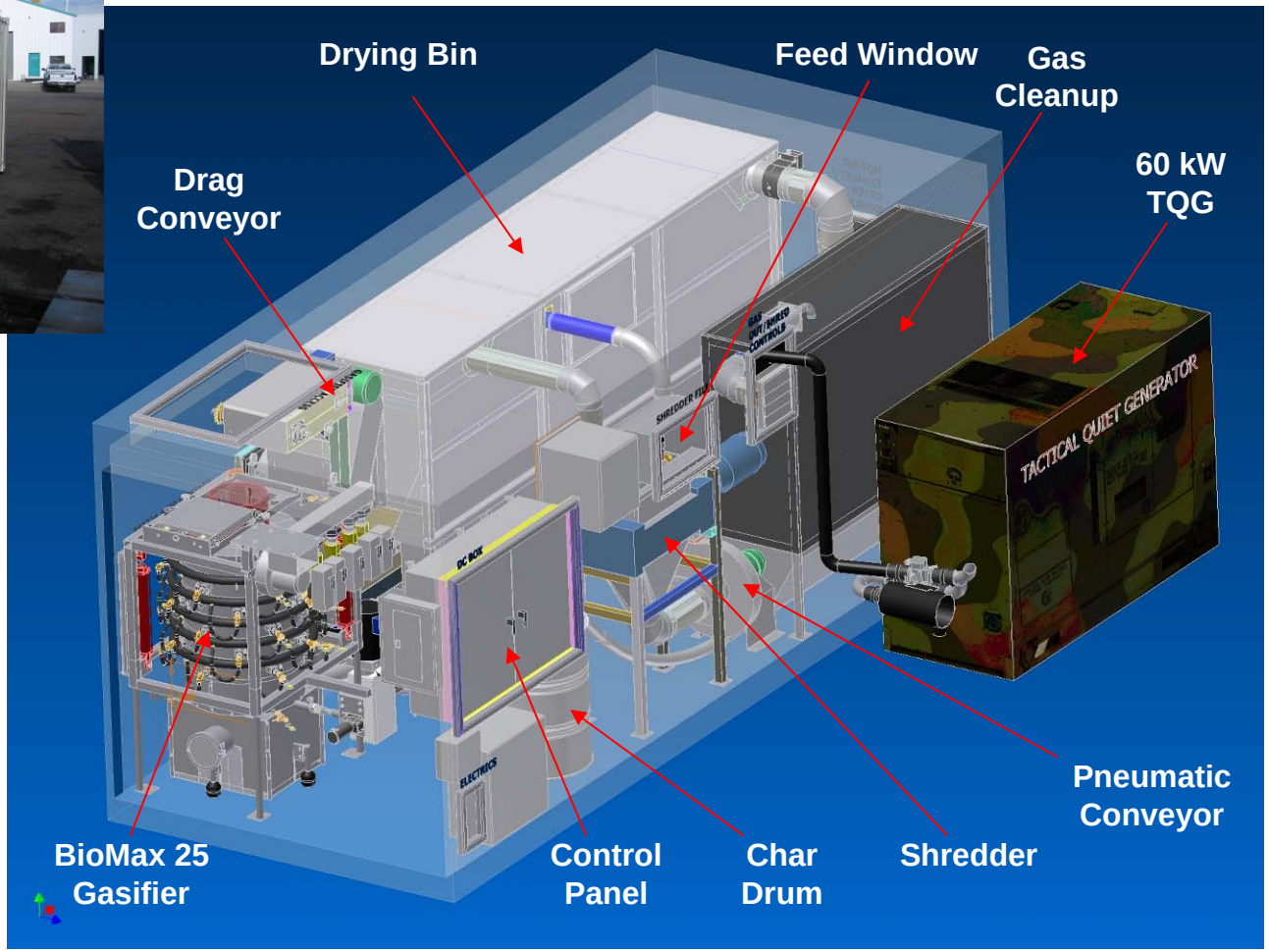
Waste generated feeding 300 troops a single UGR dinner

Downdraft Gasifier

Community Power Corporation, Littleton CO

- **Approach: Stratified Downdraft Gasifier**
  - an innovative design with electronic instrumentation and active air controls to optimize the process
- **Reduces dry feedstock to fuel gas and char/ash**
  - the clean producer gas can be used in an internal combustion engine
- **BioMax® pre-commercial system converts woody biomass into electricity and heat**
  - markets include small industrial, agro-processing, and rural electrification

Downdraft Gasifier



Containerized WEC with major sub-systems identified

Downdraft Gasifier WEC

Routine Operation and Maintenance

- **Automatic Operation**
  - Computer controlled
  - Transports feedstock from shredder to drying bin to gasifier
  - Adapts to feedstock and electrical load changes
  - Identifies faults
  - Alerts and instructs operator
  - Logs data

- **Operator Requirements**
  - Minimal computer skills
  - Some mechanical aptitude
  - High school education
    - Example: BioMax® 15 operated by Ag students at North Park High School in Walden, CO

- **Operator's Duties**
  - Load the shredder
  - Respond to operator alerts
  - Remove sack of char from char drum
    - About daily
  - Perform routine maintenance
    - Weekly as required

Flexible Photovoltaics – Why?

Travel Lighter, Stay Longer!

Problem: ***Current power sources are heavy, expendable and detectable, not directly integratable into Warrior Systems, and do not have sufficient density for extended missions.***

Known – Photovoltaics (PV) convert "free" light energy into electricity with no noise, moving parts, fuel consumption or pollutant emissions.

Less known – PV technology has changed significantly over recent years… that technology now allows PV's to be flexible and lightweight!

Photo courtesy DOE/NREL

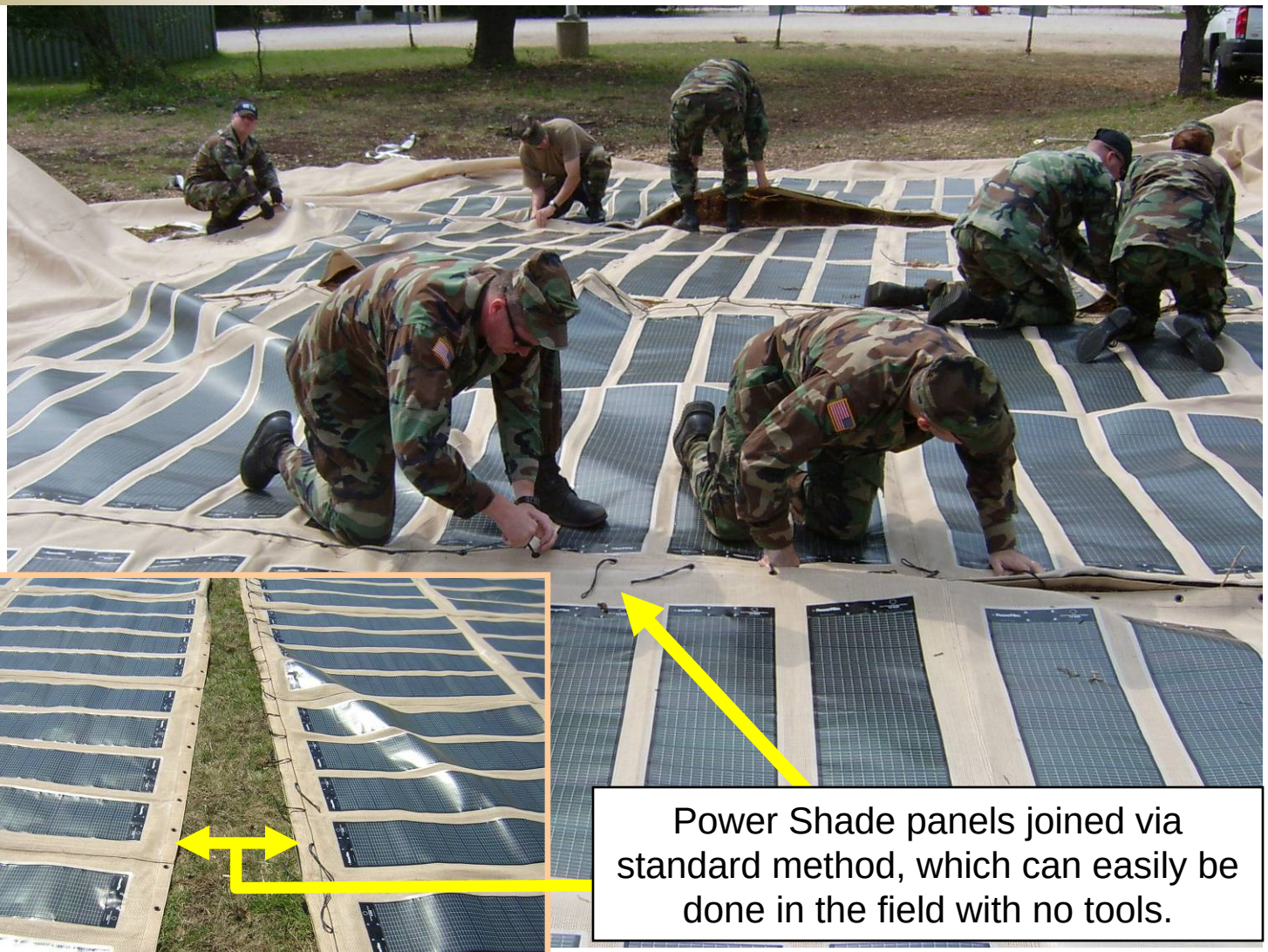
Today's PV's can provide many benefits to the military…..

Shelter Integrated Flexible PV Power Shade

Application:

- Solar shade w/ integral PV power, reduces solar load 80% – 90%
- Small version provides 1 KW of PV power
  - Designed to fit over: MGPTS small, 16’ TEMPER
- Medium version provides 2 KW of PV power
  - Designed to fit over MGPTS medium, 24’ TEMPER
- Modular expandability

Power Shade
Easy field assembly



Power Shade panels joined via standard method, which can easily be done in the field with no tools.

Shelter Integrated Flexible PV 2 kW Power Shade

Give them one prior supervised set-up, and 20 minutes later…

…these Soldiers are enjoying the reality of shade AND silent electrical power with no logistical fuel tail!

"TEMPER fly and QUADrant"

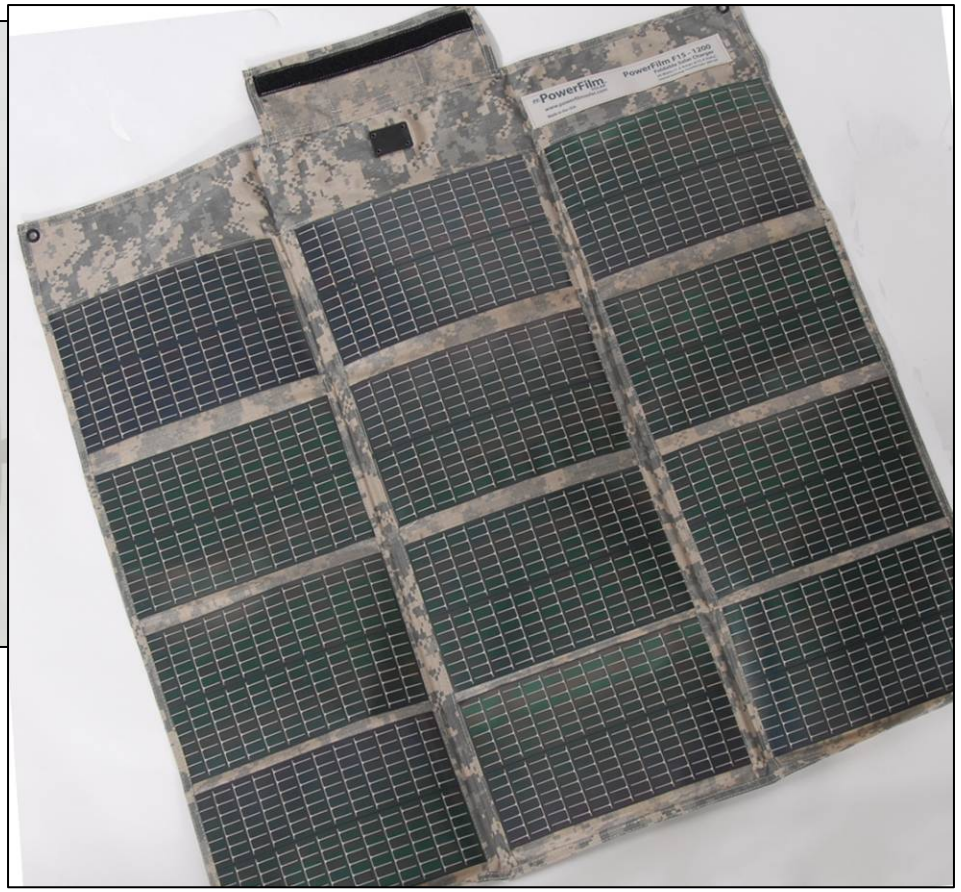
Application:

- TEMPER PV fly is a "drop-in" replacement for existing tent fly
  - Provides ~750W of power
- QUADrant is ¼ of a TEMPER fly
  - Provides ~ 200W of power
  - Modular expandability, flexible ground or frame mounted use.

TEMPER Fly

QUADrant

Foldable PV units



Portable power in the field

- 5, 10, 20, 30 and 60 watts
- 12V and 24V DC output
- Easily deployed
- Compact and lightweight (6oz for 5w unit)
- Daisy chain for modularity

Roll-able PV Mats

Application:

- Versatile PV power supply….Roll out anywhere for instant power
- Multiple sizes to match the need - .3, .6, and 1.2 Amp units
- Stores in it's own pouch
- Rolls tight.. Rolls to under 5" diameter for even the largest unit
- Roll-able units with Desert tan and Olive drab substrate available

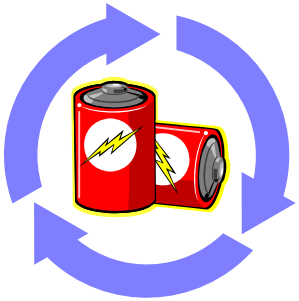
Technical Specifications:

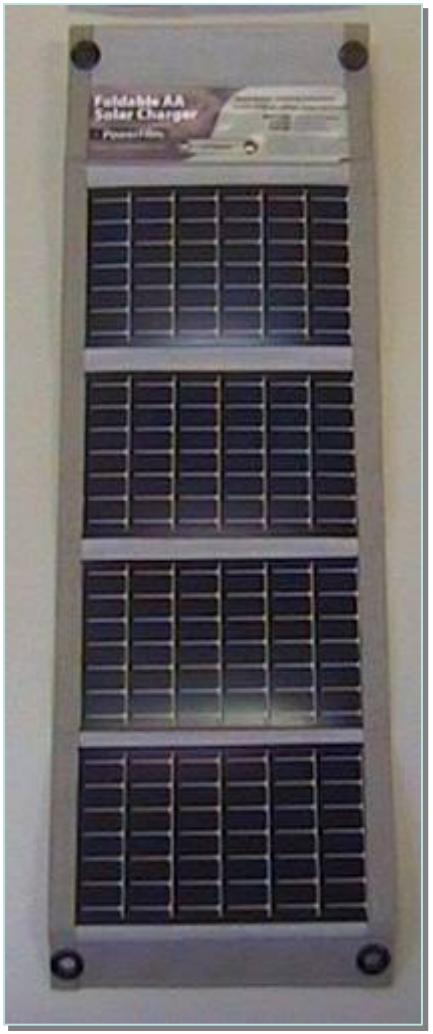
	Operating Voltage (V)	Operating Current (Amps)	Weight (lbs./kg)	Rolled Dimenstions (in/mm)	Unrolled Dimensions (in/mm)
PowerFilm® R15-300	15.4	**.3**	.6 .29	11.5x4x3.75 292x101x92	11.5 x 21 292 x 531
PowerFilm® R15-600	15.4	**.6**	1 .46	11.5x4.25x4.25 292x108x108	11.5 x 38 292 x 972
PowerFilm® R15-1200	15.4	**1.2**	1.9 .88	12x4.25x4.5 305x108x114	12 x 73 305 x 1858

Flexible PV Charging Solution: AA battery charger

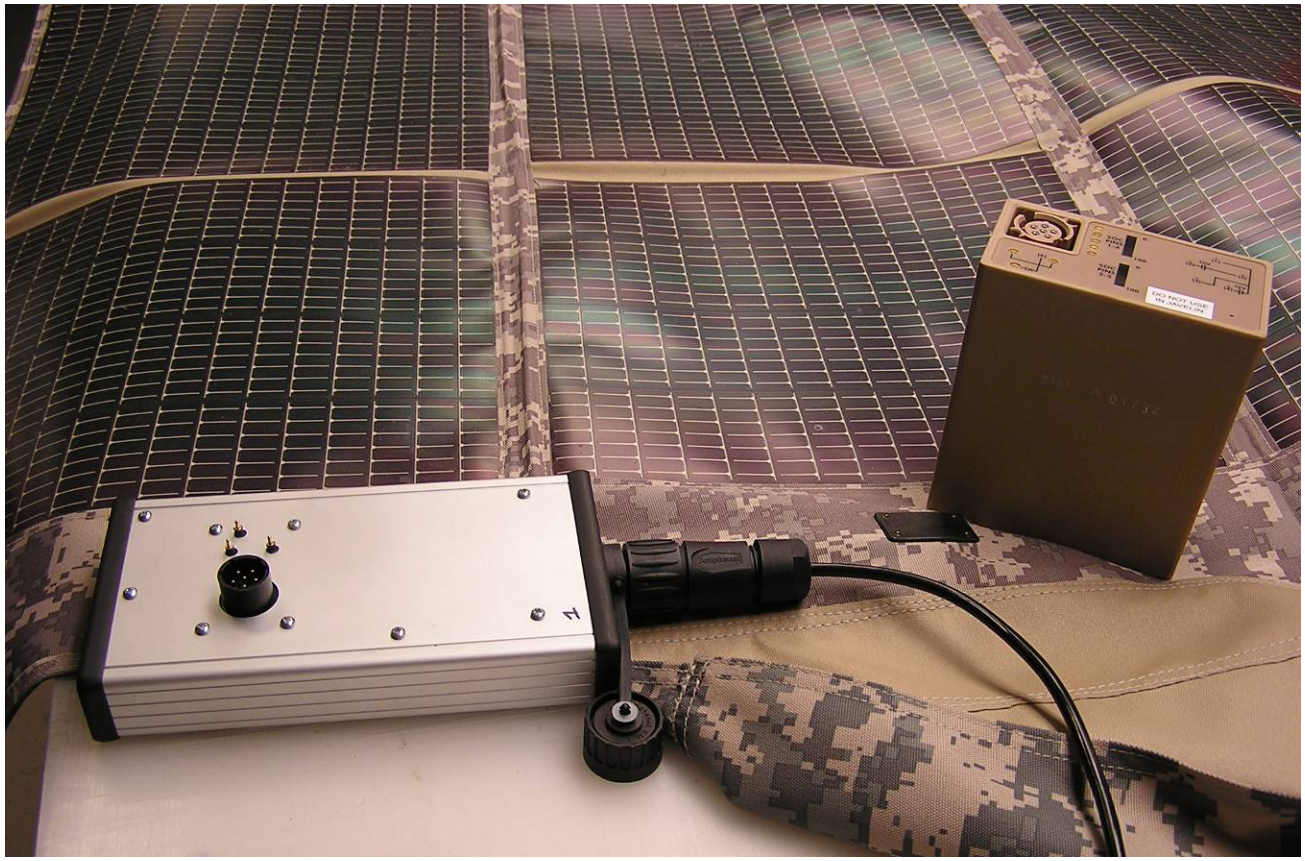
***Specifications*:**

- **Capacity:**
  - Two or Four NiMH or NiCAD AA batteries
- **Weight (w/o batteries): ~ 3.4 oz**
- **Approx time to charge**
  - Full Sun: ~ 4 hours
  - Partly cloudy: ~ 6 - 8 hours
  - Overcast: ~ 16 hours





Flexible PV Charging Solution: BB2590 / BB390 battery charger



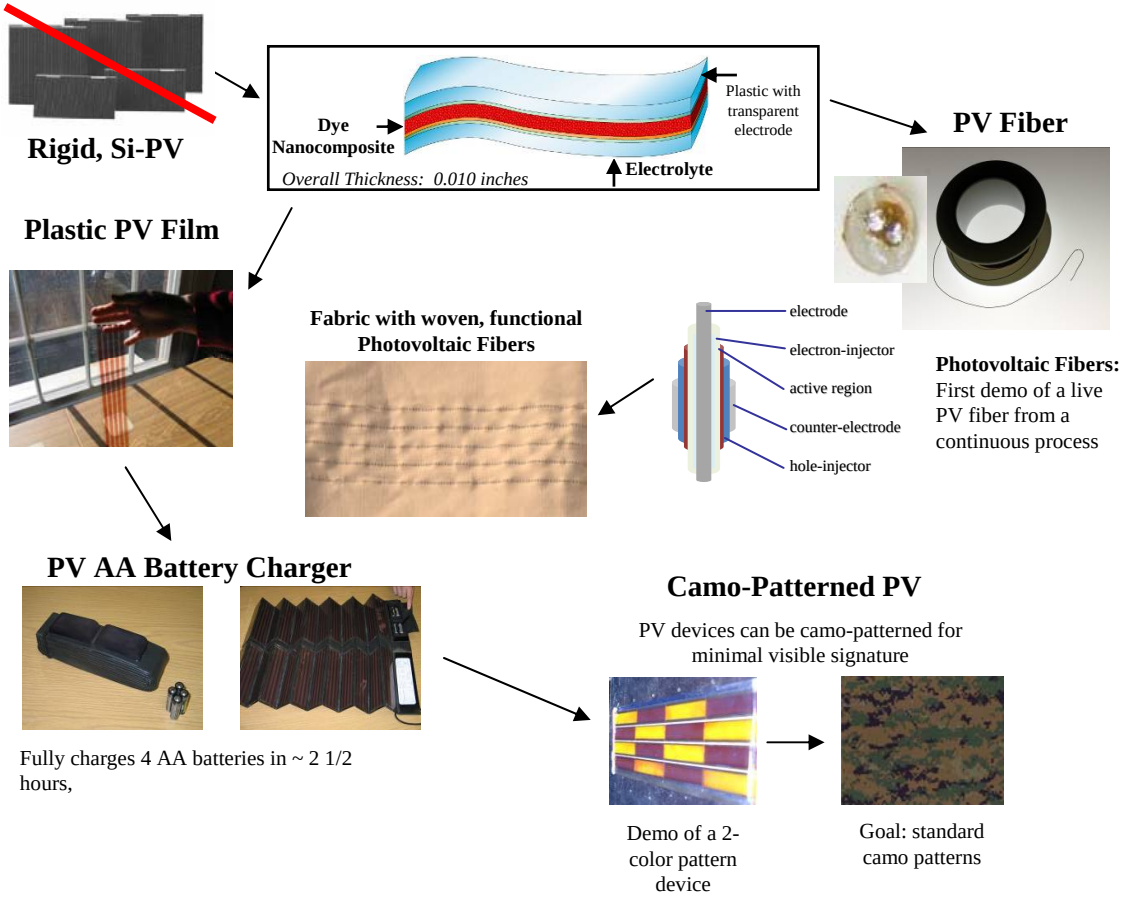
- 1st iteration design prototype shown
  - New package & electronics ~ 1/4 size and >90% efficient!

Next Generation Solar Cells for Lightweight, Conformal and Renewable Power

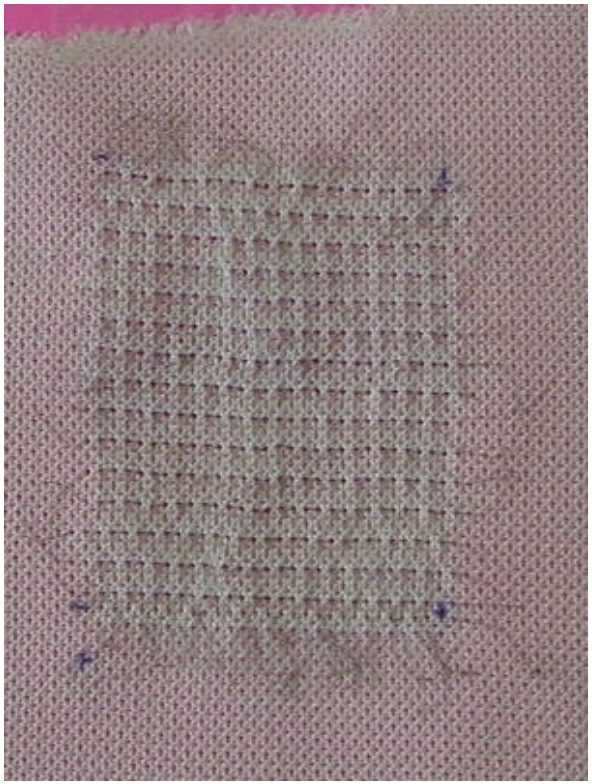
The core technology is based on very thin (< 3 sheets of paper thick) dye nanocomposite Photovoltaic (PV) coatings that are applied to flexible plastic films in a cost effective roll-to-roll manufacturing process.

Applications:

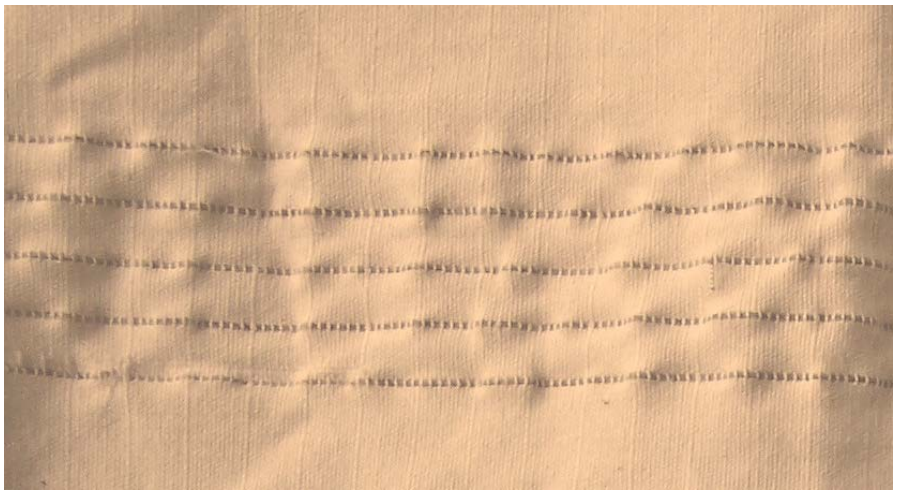
- Battery Chargers: Portable (AAs, BB2590, etc.) and Stationary – kWs power from larger surface area structures (shelters, vehicles – manned and unmanned)
- Hybrid Power: Complement to generators
- Sensory Arrays: Minimize power re-supply for remote, distributed sensor arrays
- Modular Power: Provide Pockets of power, minimize wires/connects

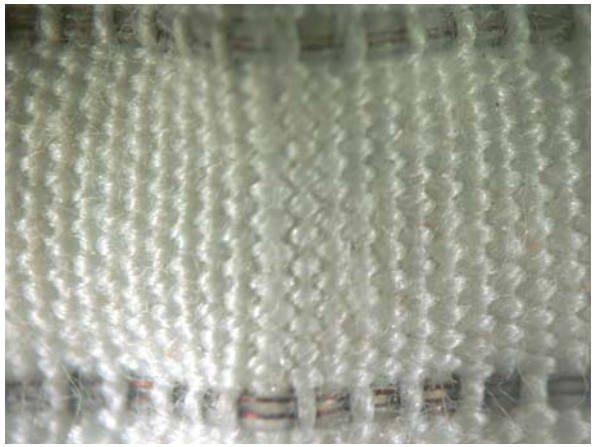


PV fibers in fabrics



Hand-woven





Machine-woven

After conventional machine weaving, the PV fibers still functioned

Fiberboard - Problem Statement

Army, Air Force, and Marine Corps consume approximately 46.6 million operational rations each year generating 14,117 tons of packaging

Meals Ready-To-Eat (MRE)/Unitized Group Ration (UGR) – 10,000 Tons of Fiberboard Annual Waste with Removal Cost at $50/Ton = $550,000
*2002 Procurement Statistics

New technologies producing lightweight biodegradable fiberboard are needed to reduce packaging waste and disposal costs

Meal, Ready-to-Eat (MRE) Pallets and Cases

Fiberboard Initiatives

Strategic Environmental Research & Development Program (SERDP) – Lightweight and compostable packaging

JSN 07-05 - Multi-Functional Secondary Packaging

Sustainable Technologies for Ration Packaging Systems (STRaPS) – FY12

Technical Objectives

Objectives:

- **Produce new lightweight fiberboard materials, biodegradable polymer-coated fiberboard and paperboard that can be converted to a valuable byproduct, compost.**

- **Produce environmentally friendly materials that meet the operational and performance requirements of combat ration packaging.**

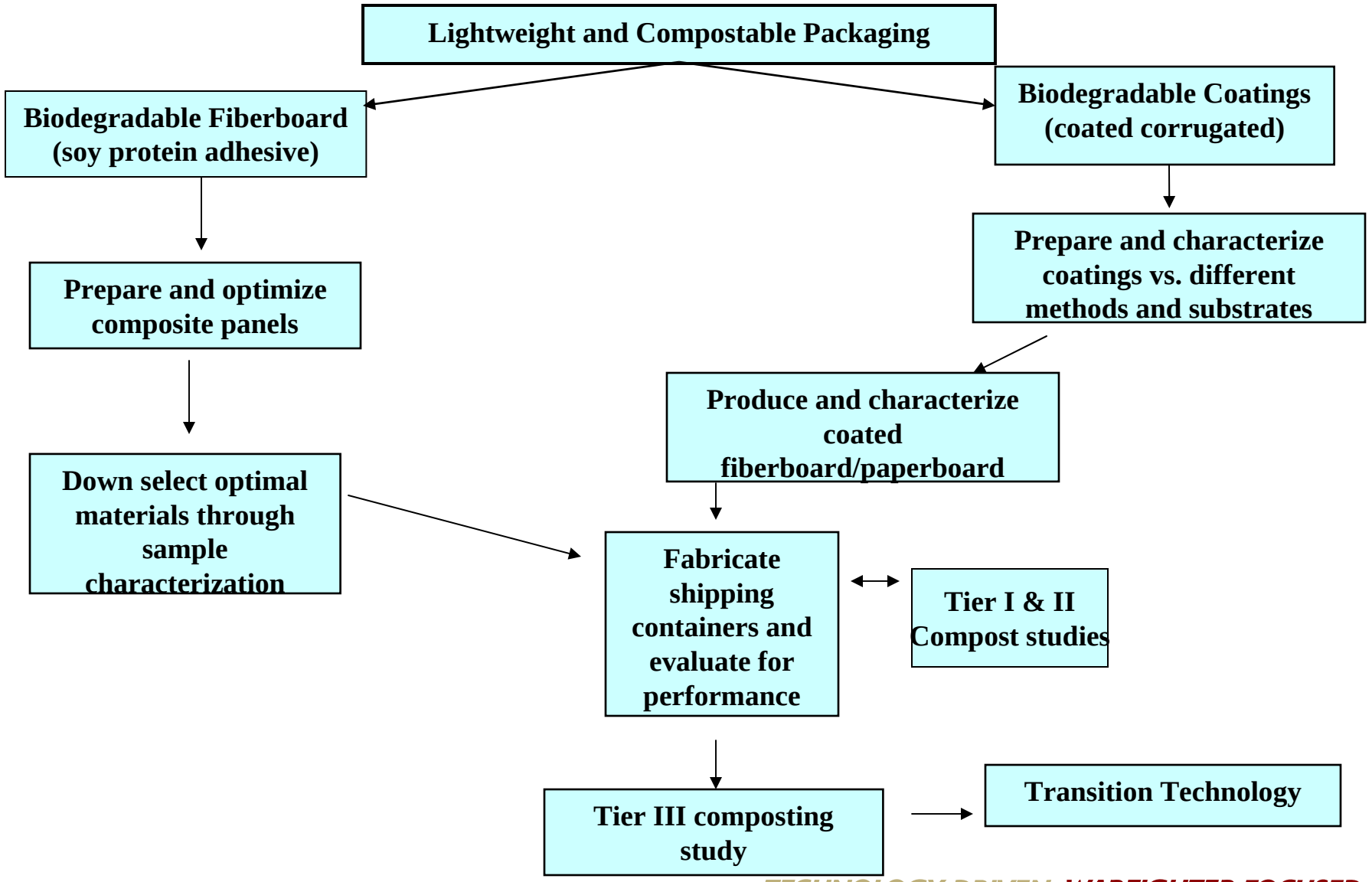
MRE Food Component and Storage Shipping Containers

MRE MEAL

MRE CASES FOR SHIPMENT

UGR

Technical Approach



Soy Protein Fiberboard

Fiberboard preparation

Soy protein

Modification

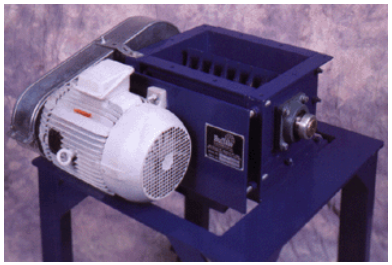
Soy Adhesive

Fiber

Rotary drum

Mixing and Coating

Drying



Lump breaking

Reinforcement

Molding

Hot Pressing

Fiberboard

Fiberboard Preparation

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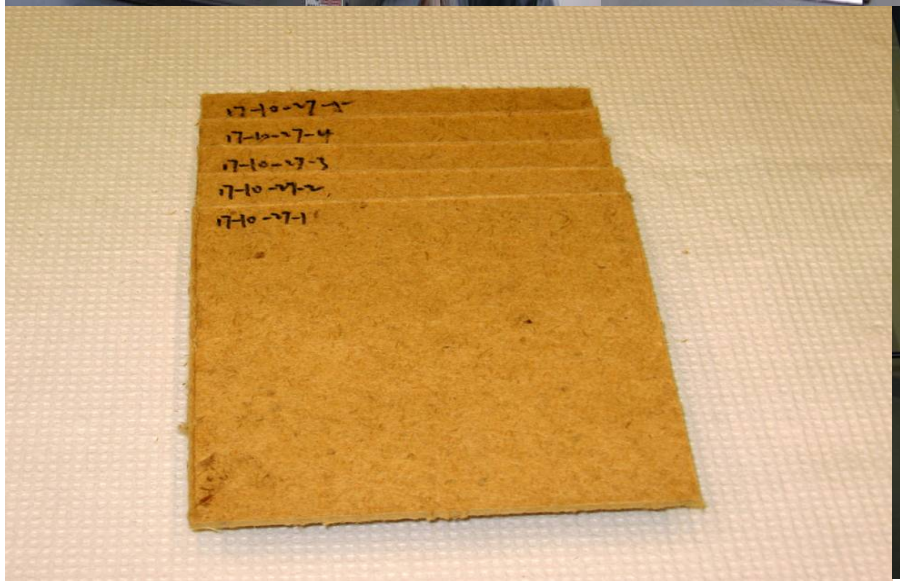
Fabrication of Fiberboard



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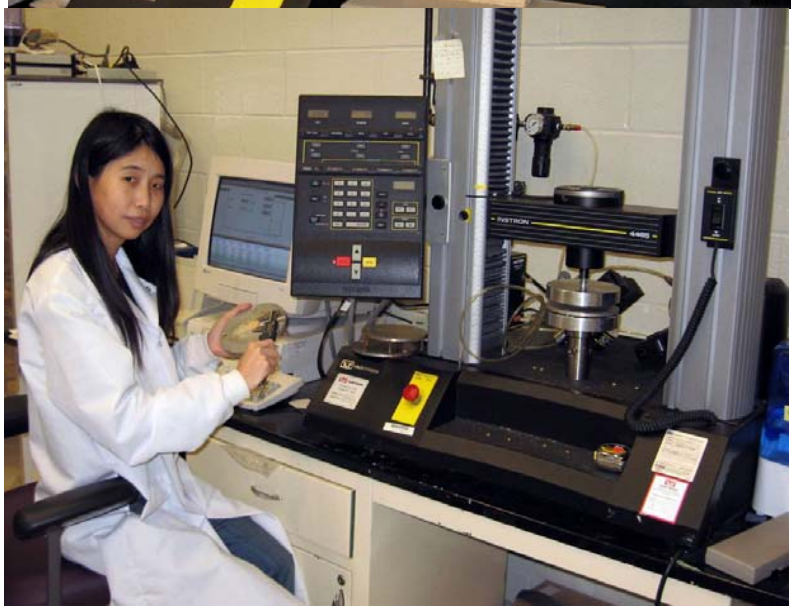
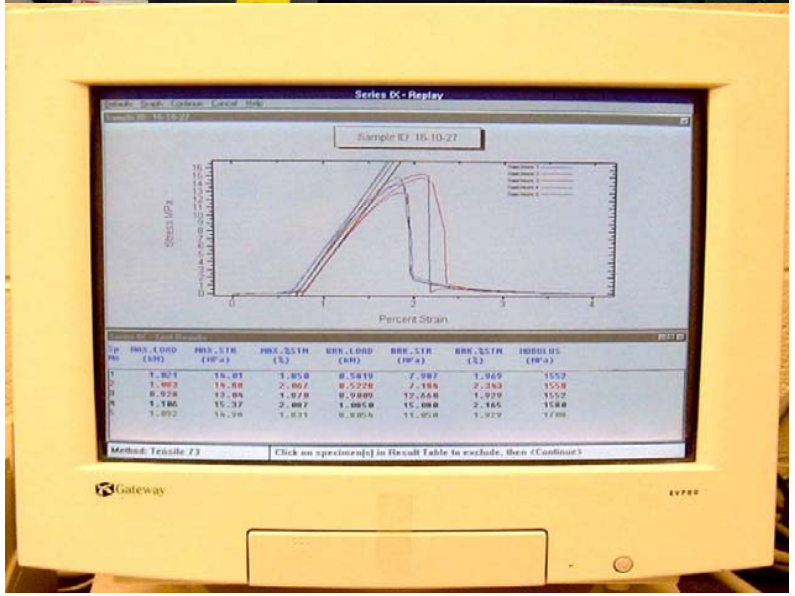
Mechanical Testing of Fiberboard





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Double-Face Corrugation Process

Glue station - single face / liner join

Finished sheets

Cutting Section

Finished Sheets

Heating Section

Cooling Section

Glue Roll

Single Face Liner

Glue Roll

Medium

Double Face Liner

Heating Section

Cutting/Scoring Wheels

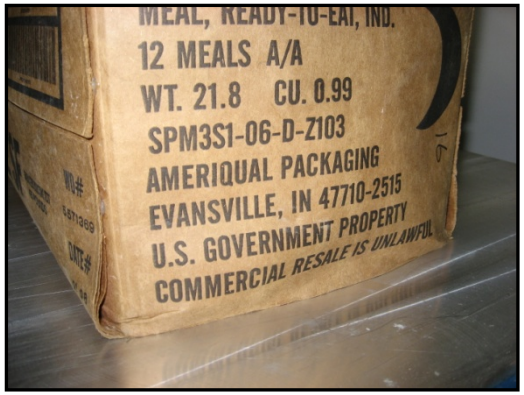
Roll Station for Liner

Roll Station for Medium

Container Samples

RSC WD with 12 MREs

MRE SF after compression



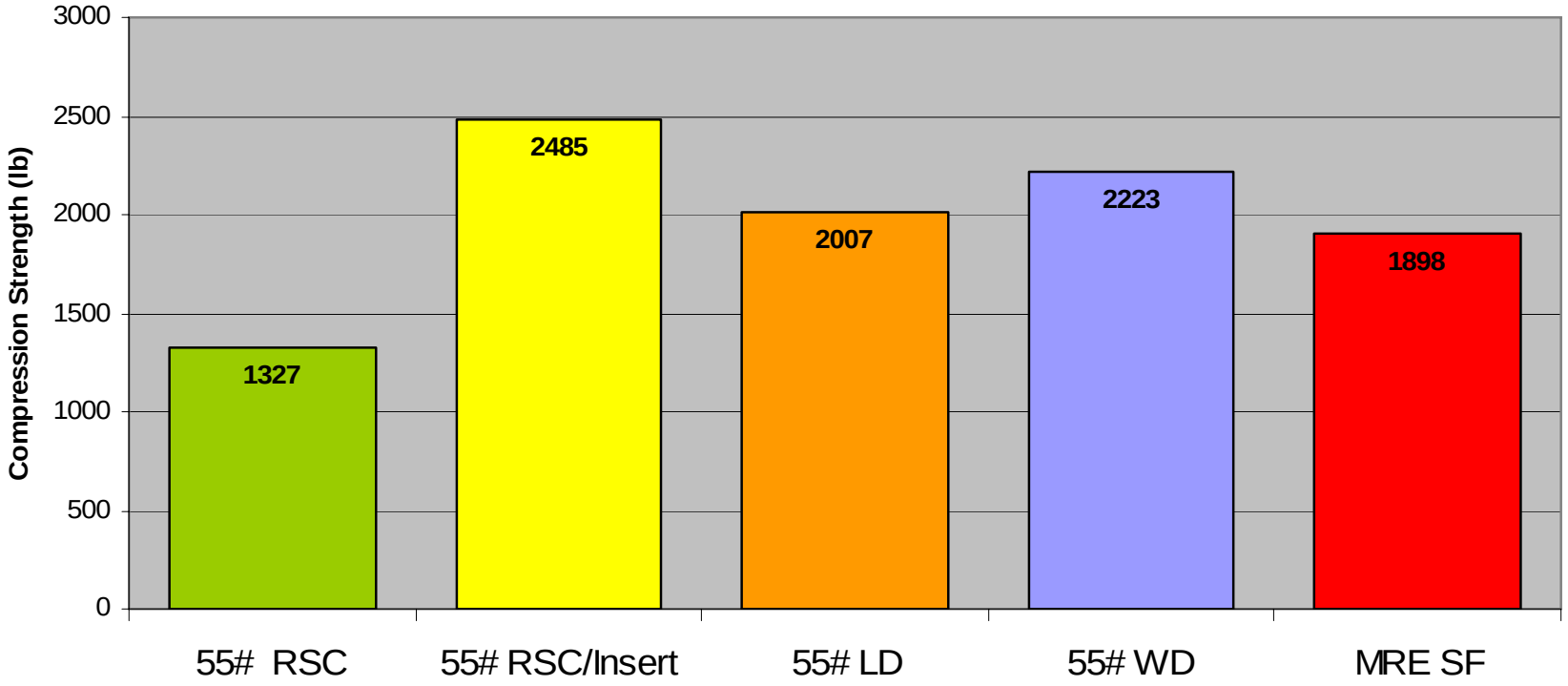
MRE SF during compression

RSC WD after compression

RSC LD after compression

Compression Analysis

Load Chart MRE Filled



Spray Test ASTM D951-99

Control MRE Containers

Current MRE SF – no significant deflection after 4 hr spray test

Conditions

Duration – 4 hours

Intensity - .8 GPM

Water Temp. – 72F

Bottom box of SF stack
note stress at glued flaps

Spray Test ASTM D951-99

Coated Corrugated Prototypes

Showed some deflection on bottom two boxes

Conditions

Duration – 4 hours

Intensity - .8 GPM

Water Temp. – 72F

Spray Test ASTM D951-99

Conditions

Duration – 4 hours

Intensity - .8 GPM

Water Temp. – 72F

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Composting

Composting Studies

1. **Conduct biodegradation tests in compost (Tier I, Tier II, and Tier III)**

2. **Use fiberboard along with food waste / paper / wood chips etc. to prepare compost and test the quality of compost.**

   Conditions: C:N ratio, moisture, air filled pore space, oxygen, pH, temperature of compost

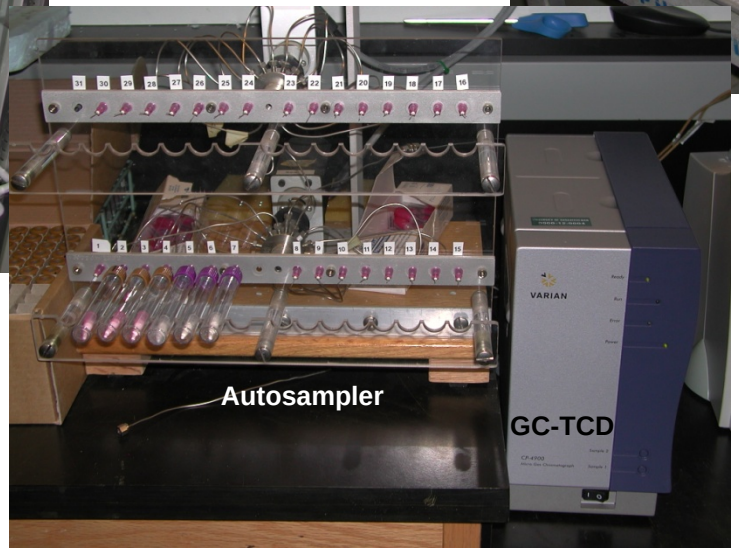
Tier I Testing: Mineralization studies

- **Respirometry**
  - In accordance with ASTM 5988
  - Determines the environmental biodegradability of the test material
  - Lab-scale test based on simulated windrow composting conditions
    - Measures the conversion of structural C to CO_2-C
  - "Compostable" material yields 60% conversion of structural C to CO_2 within 180 days under standard test conditions

Tier I Testing: Mineralization studies

Composting vessels in incubator (52 ± 1ºC)

Headspace samples collected and transferred to vials



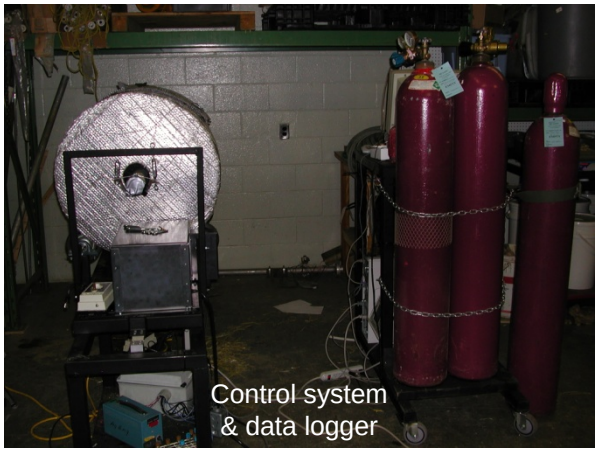
Gas samples analyzed using GC

Tier I Testing Results

Percent Biodegradation at 180 days

	Mineralization	
Test Material	$ThCO_{2\ (\%)}$	Deviation (+/-)
Cellulose powder (positive control)	**75**	**5**
MRE Solid Fiberboard Container	**86**	**11**
MRE Corrugated Liner	**87**	**19**
Soy Protein Fiberboard	**68**	**13**
Coated Corrugated Fiberboard	**61**	**9**

Tier II Testing: Weight Loss

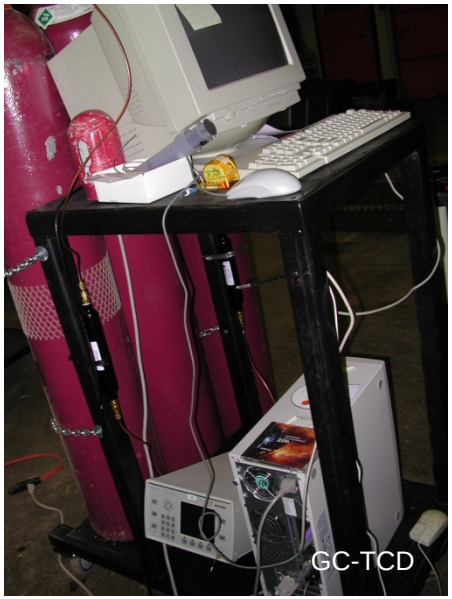


Bench-scale (200 L) composter

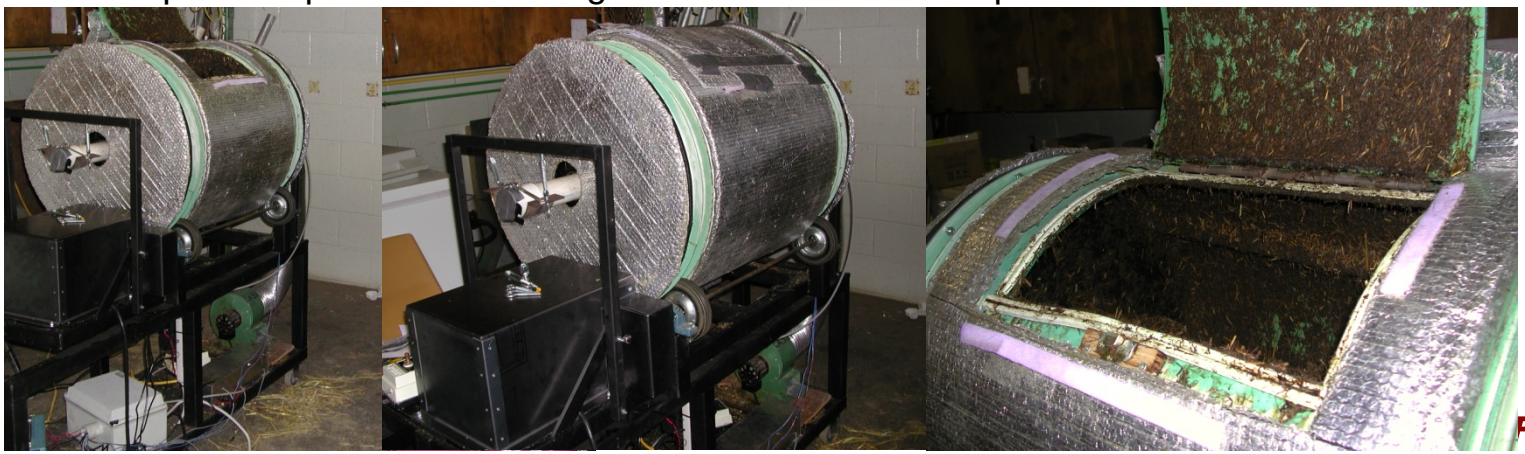
Composter is turned once per hour; temperature & O_2 levels are monitored at set intervals

Compost is aerated (forced air system along central core) if temperature > 58ºC or if O_2 concentration < 15%

Gas samples are analyzed using GC



Test samples are placed in litter bags and buried in the compost matrix

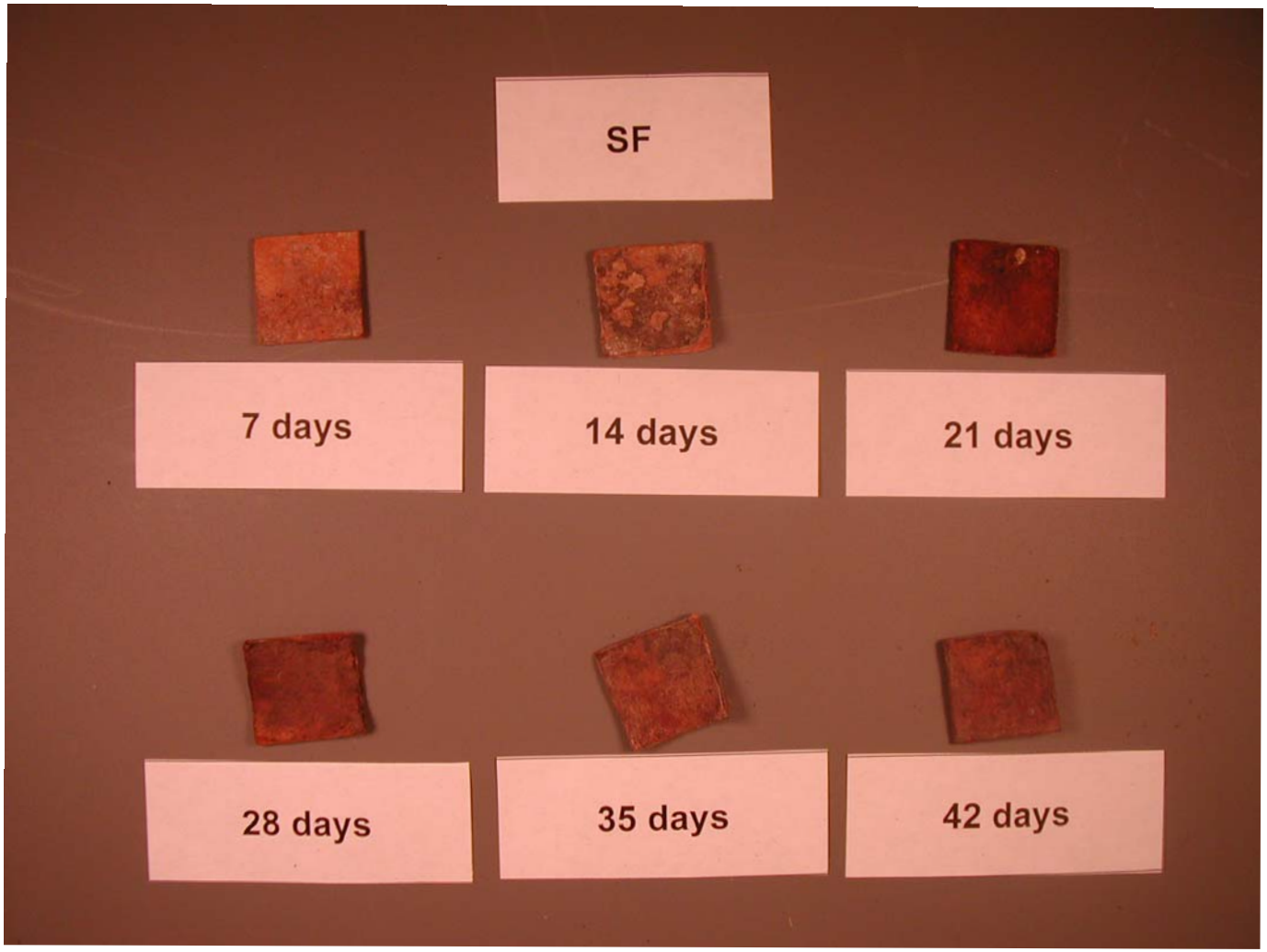


FOCUSED.

Tier II composting: Results

Time (d)	- - - - - Weight Loss (%) - - - - -					
	V2S	V3C	MRE-liner	MRE-box	Coated Board	SF
7	**0.76**	**0.64**	**1.11**	**1.72**	**1.06**	**2.40**
14	**4.84**	**3.39**	**1.50**	**8.57**	**7.56**	**8.83**
21	**8.59**	**6.48**	**9.03**	**11.17**	**10.92**	**11.59**
28	**12.11**	**9.38**	**10.09**	**12.91**	**18.43**	**17.04**
35	**17.81**	**12.84**	**14.07**	**20.71**	**18.43**	**15.35**
42	**18.91**	**14.13**	**16.45**	**24.03**	**17.71**	**15.30**

Solid Fiberboard



Lightweight & Compostable

Focus Areas

- **Compression Strength**
- **Bursting Strength**
- **Rough Handling**
- **Water/Moisture resistance**
- **Weight, Waste & Cube**
- **System Performance**
  - Transport/Storage
  - Material Handling/Use
  - Disposal

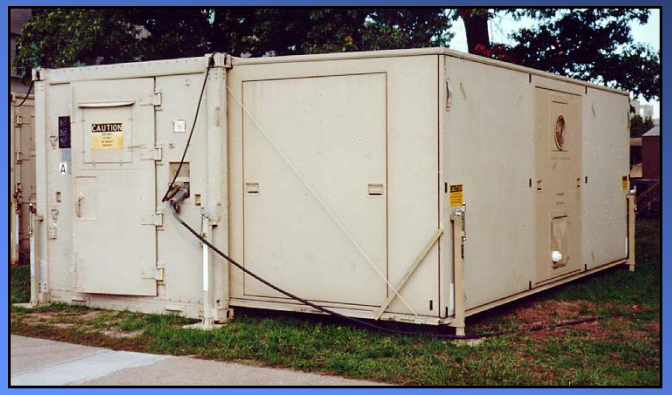
Benefits

- **Weight Reduction**
  - 3.6 million lbs per year!
- **Material Reduction**
  - 20%-40% savings in weight vs. MRE container
- **Compostable**
  - Coatings, fiberboard, etc.
- **Repulpable**
  - New coating allow fiberboard to be processed at the mill
- **Recyclable**
  - Move containers out of the waste stream and into the recycling chain

Modular Extendable Rigid Wall Shelter (MERWS)

Army ISO Shelter Family

ISO 1 :1



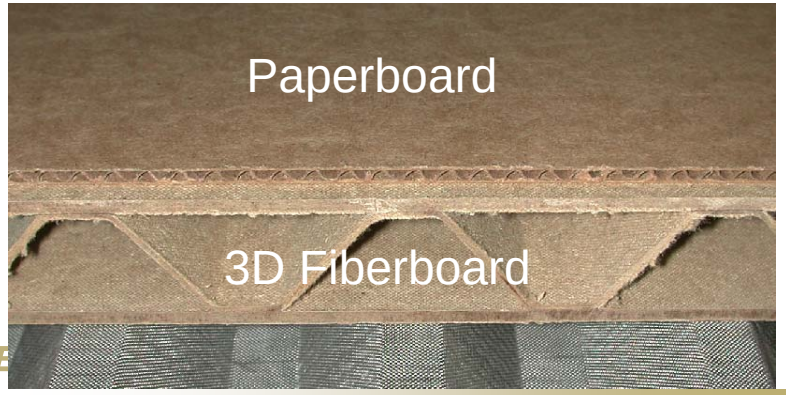
ISO 2 :1

ISO 3 :1

Inside ISO 3 :1

3D Engineered Fiberboard Investigation

- **Originally developed to facilitate housing and furniture industries, make use of forest and barnyard "waste" materials and consumer wastes**
- **Potential to replace "specialty" nomex honeycomb core with mass produced core material**
  - Lower cost due to economies of scale
- **Potential to set new standard for next generation of shelters**
  - Low cost one time use structure
    - Medium term deployment (3-5 years)
    - Biodegradable
    - Reduced logistics burden
- **Potential to reduce ISO Shelter cost**
  - Lower manufacturing costs
  - Lower materials cost



Warfighter Recommended, Warfighter Tested, Warfighter Approved™

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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