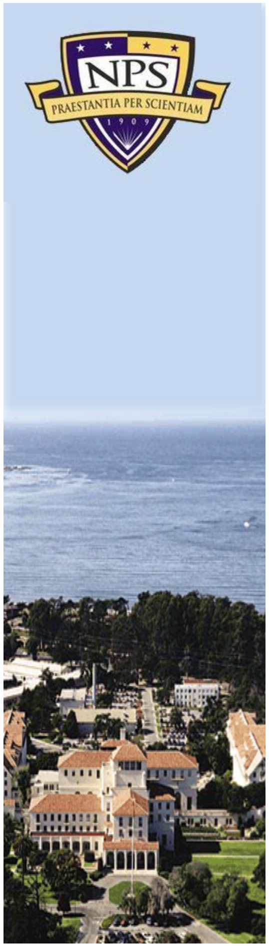
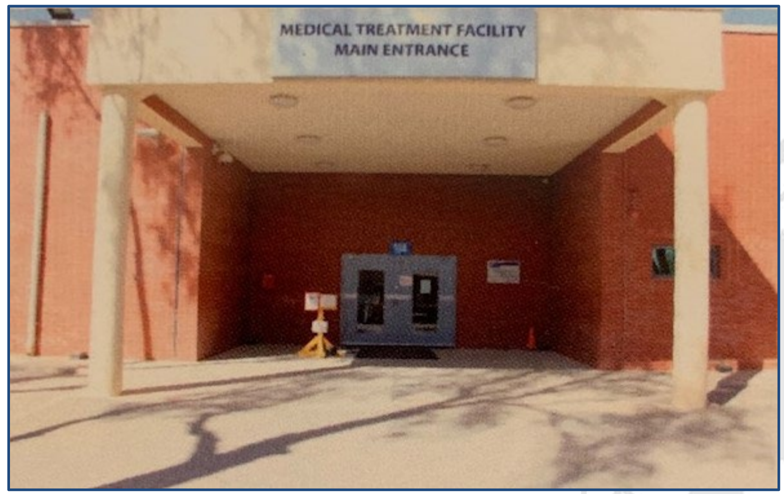


Exploring the Potential for 3D Printing: Medical Logistics in Operational Environments



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Motivation

MOMENTS BEFORE THE OCTOBER 2018 KANDAHAR SHOOTING.

Mass casualty events in forward deployed locations are exceptionally challenging environments:

- Demand is unpredictable and erratic
- Medical units are often at capacity, but can't close to new demand
- Uncertain number of patients
- Prolonged patient care
- Difficult resupply

Supply shortages during these mass casualty events often result in medical personnel using non-standard workarounds.

Research questions

- Does 3D printing have the potential to positively affect medical logistics operations in distributed maritime operations (DMO) environments?

- If so, which Class VIII(a), i.e., consumable, medical supplies show high potential?

Research approach

Two-Phase Qualitative Analysis

Phase 1:

- Case analysis of mass casualty events at NATO Role 3 military medical unit (MMU)
- Data sources: Interviews and documents
- Output: Identify and describe critical incidents and process failures

Phase 2:

- Exploratory investigation of early 3D printing adoptions
- Data sources: Interviews of subject matter experts
- Output: Identify and describe feasible uses for 3D printing in medical supply and logistics context

Results:

Integrate phase 1 and 2 to make recommendations regarding the feasibility and potential uses of 3D printing to mitigate medical supply breakdowns in operational and distributed environments.

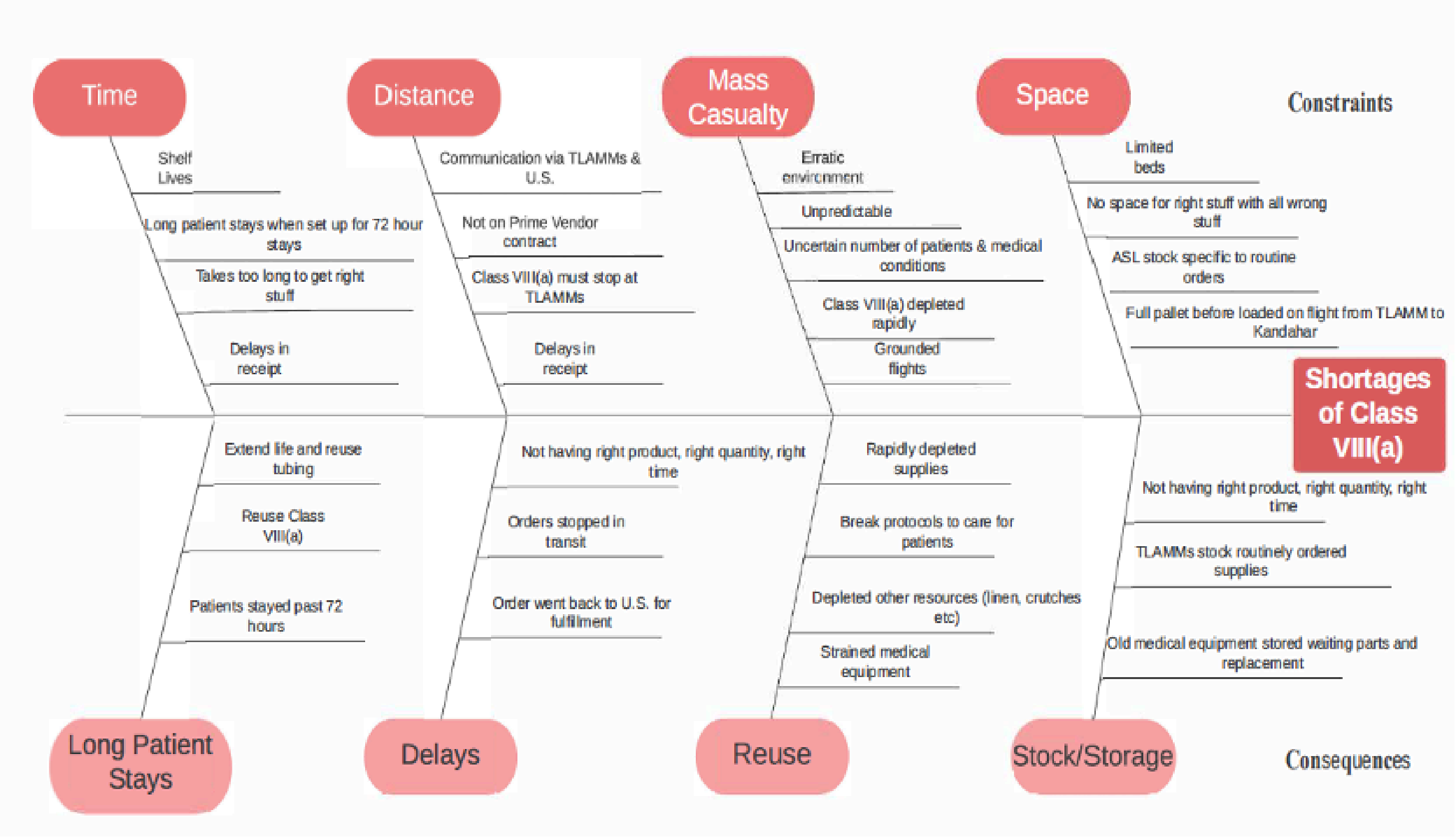
Analysis and findings

Critical events during a 9-month period provided sample insights into burn rate during mass casualty.

Driver	Outcome
Providing intensive care beyond the specified 72 hours trauma care timeline. More time and intensive care than facility was intended to provide.	Personnel used supplies quickly. Medical conditions required more rapid use of flushes, which depleted supply of flushes. Personnel required to improvise flushes.
Facility and supplies are not designed for highly contagious patients, with an open ward and limited PPE.	Personnel forced to break infection control protocol because of rapid depletion of PPE and secondary resources.
Supplies not adequate for types of procedures.	Facility ran out of surgical items; forced to request from other facilities, delaying patient's surgery and discharge.

Analysis and findings

Four major constraints, causing shortages, emerged from this analysis: time, distance, mass casualties, and facility space. These constraints resulted in long patient stays, delays, reuse, and stock/storage.



Analysis and findings

We identified six important Class VIII(a) medical supplies rapidly depleted during mass casualty events with potential for 3D printing: **syringes, IV tubing, cranial kits, implants, suction valves, and suction canisters.**

Key Shortages	Low	Moderate	High
Syringes		X	
IV Tubing	X		
Cranial Kits	X		
Implants			X
Suction Valves		X	
Suction Canister		X	

Analysis and findings

Possible constraints: Our subject matter experts assessed the potential for 3D printing these items, based on many constraints, e.g., materials (rubber stoppers in syringes), medical constraints (risks of "leaching" in syringes), required printing capacity (implants), and others.

Key Characteristics	Interview Participants
Internal/external to the patient	"An implant is printed with materials sustainable within a patient, approved by FDA"
Materials required	"It's not just being in the patient, it's the material of the object that matters."
Watertight	Watertight integrity critical for patient use
Flexibility of the object	"Material/objects that are rigid are easier to print than flexible materials"
Technology requirements	"3D printing watertight objects requires specific printing technologies; concerns of leaching"

Analysis and findings

Interesting additional SME contributions

- **Antibiotic bandages** - SMEs suggested as feasible and desirable for 3D printing in operational or distributed maritime operations (DMO) environments
    - Shifts trauma care focus from medical facility to battle-field
    - Leach antibiotics over hours to days, supplement as a splint
    - Offer potential to increase survivability during the **golden hour**.

- The greatest perceived value of 3D printing on-site comes from relieving the fulfillment lead-time
    - Class VIII(a) consumable supplies <u>must</u> come from suppliers in the continental US

- Medical repair parts are also a significant opportunity for 3D printing in this environment.

Analysis and findings

- Some Class VIII(a) consumable medical supplies are logistically better supplied by manufacturers in bulk, not via 3D printing.
- Specific product characteristics have limited testing of 3D printing for Class VIII(a) medical supplies, e.g., watertight integrity requirement for syringes.
- Both medical supplies and 3D printing raw materials have specific characteristics that require further research and testing. This research identifies likely value-added candidates to prioritize for testing.
- The analysis identified that medical equipment repair parts pose significant problems in receiving in operational environment due to backorders. This is an area for future research.

Conclusions

- 3D printing **has** the potential to positively affect medical logistics operations in DMO environments.
  - Some supplies are more amenable to 3D printing
  - Limitations include product characteristics (e.g., watertightness) and material characteristics (e.g., rubber stoppers in syringes)
  - Small multi-purpose 3D printers are light, easy to use, and could deploy with medical units both on land and sea.
- Printing antibiotic bandages has the potential to deliver medication during transit prior to surgery. It could improve patient outcomes, increase survivability, and potentially relieve other supply shortages.
- Medical equipment repair parts represents another potential contribution for 3D printing.

Recommendations

- Policy - Extend of the length of time NATO Role 3 MMU is set up to care for patients beyond the 72-hour window; stock supplies appropriately for this longer window.

- Practice - Place a small printer within medical facilities in operational environments – land or sea-based (e.g., USNS Mercy) deployed to austere operational environments.

- Future study - Establish communication between 3D printing researchers and deployed medical professionals to facilitate identifying value-added future directions for 3D printing.

Questions?

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