# Point to point transportation as an alternative to convey supplies to isolated stricken areas during massive disasters by adopting sub-orbital flight system

Huai-Chien (Bill) Chang
PhD student, Department of Architecture, Faculty of Engineering, the University of Tokyo
and Co-founder of Consortium of Extreme and Space Settlements, CESS

Key Words: Sub-orbital flight, Massive crisis, Supplies delivery, Isolated stricken areas,
Point-to-point transportation, Reusable Reentry Vehicle

**Abstract**

Sub-orbital transportation has long researched by NASA or military department for carrying passengers across continents and delivering troopers to front zone in a situation of spread-out conflict. However, this paper studies possibilities of utilizing sub-orbital transportation as a new way to covey supplies to inaccessible stricken areas after massive disasters and integrates this related technologies into local rescue force.

## 1. Background and purpose

In the first decade of 21st century, there was a frequently enhanced key word that involves global environmental affair: Disasters (especially earthquakes). The inevitable climate changing along with global warming effect, it multiplies disasters in various scales, intensity and properties yearly. It can be said that an era of global complex disasters is coming ahead. The paper studies massive disasters recently such as Great East Japan Earthquake or any other major cases, has concluded that in most of which cases, crucial supplies were failed to reach to stricken areas efficiently after impact due to problems like lack of fuel, damaged roads, airports and harbours and topological barrier. For more challenging situations in the future, claim sufficient measure to transport supplies to places of distress. Sub-orbital transportation as an alternative for conveying supplies to stricken areas during massive crisis is proposed and discussed in this undergoing research.

## 2. Current emergency response and supply transportation

Current emergency supply transportation can be considered in 3 ways: land, sea and air transportation.

### 2.1 Land transportation

Usually it is referred to medium or large trucks to transport cargoes. In some cases, railway transportation is also taken into count. Benefit: 1. Highly mobility, 2. No special collecting facility is required, 3. Relatively low costs, 4. Continual transportation available. Disadvantages: 1. Easily affected by road conditions, 2. Fuel acquisition needed for long distance transportation.

### 2.2 Sea transportation

Heavy tankers or ferries are usually used in transportation. Advantages: 1. Massive transportation, 2. Reliability, 3. Long distance transportation. Disadvantages: 1. Cargo collection facilities are needed, 2. It basically depends on sea conditions.

### 2.3 Air transportation

It is transported by carriers or helicopters. Advantages: 1. No surface transportation obstacles, 2. Long distance transportation available. Disadvantages: 1. Refuel is needed for continual transportation, 2. Affected by weather conditions, 3. Airports or other specific facilities are needed.

### 2.4 Problems of supply transportation during massive crisis

If we take a look at Great East Japan Earthquake in 2011, it was difficult to obtain crucial supplies in chaotic aftermath condition and authorities were failed to coordinate logistics to reach to those suffering people in first week after the complex disaster. The reasons can be concluded to: 1. Roads and harbors are crucial but heavily damaged, 2. Lack of fuel, 3. Authorities were failed to obtain essential information, 4. Disadvantageous weather condition, 5. Topological isolation. Sufferers were forced to wait for the arrival of supplies and bear extremely coldness because of running out of heating gasoline for a week or longer. Clean water acquisition was also a great concerned.

Another case can also be mentioned is that on April 14th, 2010 in Tibet, China, a big earthquake devastated highland's villages. Due to the isolation of topology, low air pressure, damaged roads and airport, rescue team and supplies were failed to secure the appropriate accessing but only trying to enter stricken area by walk and carrying necessary relief. This caused the team members' stress and altitude sickness since they were not originally trained to deal with the unfamiliar harsh environment.

These issues pushed current transportation measures to a limit that for solving emergency response for future much more challenging complex disasters or asteroid impact event. An extraordinary way is needed to overcome these problems and for providing prompt response.

Regarding to the success of sub-orbital flight development in military field (e.g. Intercontinental Ballistic Missiles, ICBMs) and aerospace venture business (e.g. SpaceShip One), one can say that this also provides more promising way for transporting supplies to stricken areas efficiently without obstacles of damaged infrastructures or unfavorable weather conditions.

## 3. Sub-orbital emergency transportation concept

### 3.1 Definition of sub-orbital flight

"Sub-orbit" is an arch path of trajectory of which an elliptic that uses Earth as one focus of it. Sub-orbit is not a complete orbit that allowed by objects to make a full revolution. Objects of sub-orbital flight can reach space for few minutes over an altitude of 100km (Karman line), once it reaches its apogee it eventually returns to Earth's surface. It is also known as 'Ballistic flight'.

Sub-orbital flight was adopted by Intercontinental Ballistic Missiles (ICBMs) or NASA's Mercury Project in 1960s, etc. It has several advantages: 1. Flight period can be extremely shortened, 2. Travel distance is adjustable by changing its maximum altitude, 3. Object that adopts sub-orbital flight can theoretically, reach to any given destination on Earth, 4. No weather or topological obstacles during flight phase.

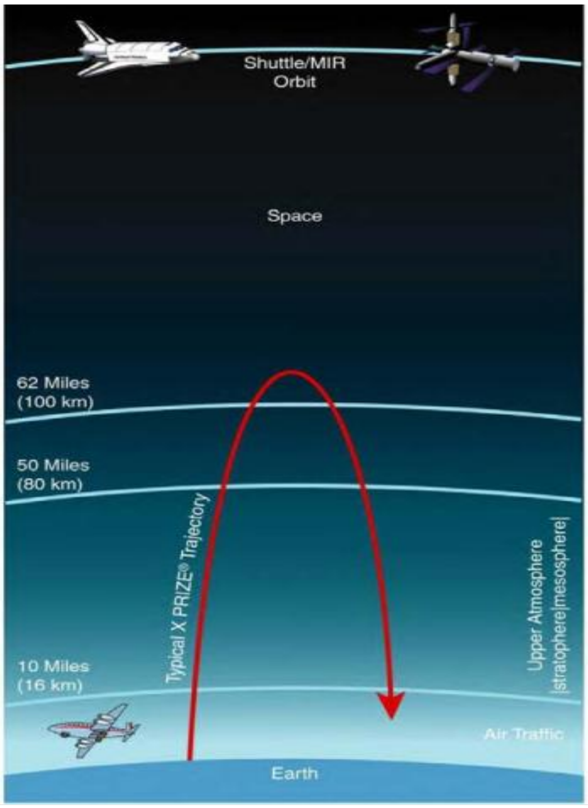



Figure 1. Concept of sub-orbital flight
(courtesy of XPrize homepage)

In this paper, the author suggested that sub-orbital flight system can be introduced as an alternative emergency supply transportation measurement after massive crisis when access to stricken area is temporary difficult.

### 3.2 SWOT analysis parameters for sub-orbital emergency transportation

Proposal of applying sub-orbital transportation for emergency response to increase the efficiency of rescue efforts has several issues that have to be identified first.

Different from current emergency transportation measures, sub-orbital transportation faces certain parameters both come from internal property and environmental challenges while it compares to air, road or sea logistics.

SWOT analysis, which discuss a system's strengths, weaknesses of internal properties and environmental challenges of external situation by opportunities and threats to the system for making improvement strategies, by breaking down sub-orbital emergency transportation into some issues accordingly.

These issues are:

**3.2.1 Strengths and opportunities:**

Smooth transportation process is obtainable; Transportation phase won't be restrained by topology condition; Less affected from weather condition of given destinations; Less environmental requirements to given destinations; Shortest path and time during transportation phase; Environment impact can be considerably controlled; Reusability is considered to launch and reentry vehicle designing.

This comes to a strategy called: Aggressive strategy, which suggests that sub-orbital transportation has highly possibility of becoming efficient emergency response by applying its certain advantages: Development of reusable launch / reentry vehicle and adoption of common utility components; No specific infrastructures or settled facility like roads or airports needed; Only to install landing gears or select flat landing areas for some safety concerns; Average time for typical ballistic trajectory flight phase needs less than 1 hour; Topology restrain can be overcomed by adopting suborbital flight solution; GIS or GPS systems are applicable for destination and landing site pre-locating determination; Weather conditions are not a main concern to achieve smooth transportation than which air carriers does, etc.

**3.2.2 Weaknesses and Opportunities:**

Departure side needs specific facility or launching complex; It has relatively less available capacity for payload of transporting vehicles; It may need time to modify the vehicles for mission requirements and launching facility adaptation before departure.

Turnaround strategy is considered to unite external resources to achieve expected results by: Diversion of conventional launching facilities, launching vehicles or establish joint collaboration between related industries for available components procurement; To improve payload efficiency, space utilization and standardized and modular system; To arrange higher projectile capability vehicles or boosters; Adopting compressible, assembled and deployable materials or supplies of payload, etc.

**3.2.3 Strengths and Treats:**

Parameters that may threaten the system to achieve the expected purposes like: Safety is concerned during transportation phase; Payload integrity is concerned and needs particular security measurement; Dramatically change of air pressure. Incoming discrimination is required at given destination for area security.

Diversification strategy is suggested here that the system should use its advantages to get over external unfavorable challenges which are already widely applied by: Using current surface based advanced space object monitoring system to secure suborbital flight plan and ballistic trajectory adjustability; Adopting aerospace fail-safe system, subsystem and redundant designing methodology; Designing a pressurized hatch and consequence subsystem and cargo stabilizing devices.

**3.2.4 Weaknesses and Treats:**

This is most unwanted situation like: Launch is available only if local weather condition permits; Launch/reentry vehicles need pre-skilled personnel to operate; Mechanical confirmation needs relatively more time and procedure before launch; Relatively higher cost of propellant requirement is needed; External cost is needed for modifying vehicles before launch.

Defensive strategy may be suggested here for the system to improve its internal property and ready for external challenges: Diversion of current / discharged missile complex or build a semibasement facility for launch standby to prevent launch vehicle system malfunction from exposing under unfavorable weather condition until launch window is available; Gathering trained personnel and integrate them into international emergency response regulation's framework for establishing a rapid responsiveness team; Looking for alternative fuel or improving propulsion system; To establish regulations or standard manual for this transportation system; Development and diversion of current aerospace common components, etc.


Fgure 2. SWOT analysis for sub-orbital emergency transportation scenario

### 3.3 Overall concept of Sub-orbital Emergency Transportation

As mentioned above, the main proposal of this paper is "accessing isolated stricken areas through space by adopting sub-orbital flight system" to secure the transportation of emergency supplies. The system consists of 3 sections: Propellant, Payload and Launch facility. Its flight profile resembles the ICBMs but without those destructive warhead atop, instead a pack of essential supply that saves lives.

#### 3.3.1 Propellant section

In this paper, rocket is considered to be a presumption propellant. However, according to different payload requirements, the capability of selected rockets alters in certain ways. For instance, in across-the-borders transportation scenario, it should be considered of intercontinental flight manner which reach to a higher apogee altitude is needed (for ICBMs, the maximum altitude can be reached to 1,200km or higher). Also, for acquiring sufficient Delta V to alter its attitude and to adjust to precise reentry phase, 2 stages rocket is concerned in this paper.

The rocket model type and launching capability in this proposal is based on ICBM derived rockets such as US's Titan rocket, Peacekeeper rocket and Russia's Dnipro rocket. They have certain launching capability of lifting commercial satellite to orbit ranging from 300km to 1,400km.

Although Titan rocket family has 4 types variations, this paper only discuss the equivalent capability of Titan II rocket which used in NASA's Gemini project with LEO (Low Earth Orbit) payload capability of 3,700kg; Peacekeeper rocket is 3,950kg while Dnipro is 4,500kg.

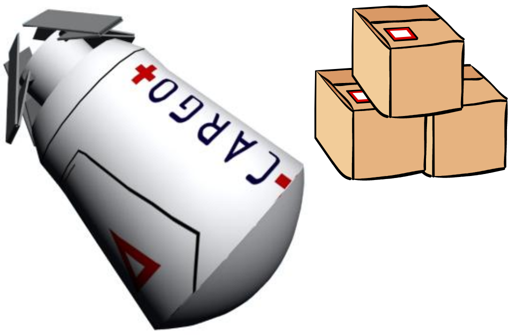
#### 3.3.2 Payload section

It is the core sector of this proposal.

This section is a Reusable Reentry Vehicle (RRV) which separates from main boost rocket after first stage's burn-out over an altitude of 100km then reenters the atmosphere and land to the given location to provide service. 2 Types of RRV are proposed: 1. Cargo RRV (C-RRV) which carries necessary supplies or materials for installing temporary shelter, 2. Service RRV (S-RRV) provides sufficient resource for local force utilization as well as the core facility of temporary medical necessity (e.g. electricity, clean water, etc.).

##### 3.3.2.1 C-RRV

The main payload of C-RRV is food and basic quantity of potable water. It contains racks, pressurized hatch and space.




Fgure 3. Concept image of C-RRV


Figure 4. Image of C-RRV deployment

The payload covers 3 to 4 days right after the disaster happened, the maximum supporting period can reach to one week until local force or ground team accessed to the place of distress. In order to set up a temporary medical facility, it can also carry necessary tools or materials. The weight of food and water is roughly calculated as below:

Table 1. Overall payload of C-RRV

| Items | Quantity (5 days) | Weight |
|---|---|---|
| Potable Water | 49~110 households | 3,920kg~8,800kg |
| Freeze-dry Food* | 300 households | 2,100kg~2,800kg |

* Reference: SUVIVAL® FOODS

##### 3.3.2.2 S-RRV

It provides hygiene management and energy service trough producing clean water and electricity/heat. It is also the core component of temporary medical facility and related machinery.

The energy source comes from Regenerative Fuel Cell (RFC) with solar power system which is known by its variety use in aerospace fields. RFC produces electricity, heat and clean water then solar power system electrolyte input sewage, which comes from local people or medical liquid waste, into hydrogen and oxygen to feed the fuel cell and so on. The heat produced by the system may allow temporary medical facility to use and provide simple hot shower for local people's hygiene. Communication or diagnose devices may use the solar power either.

Figure 5. Concept image of S-RRV

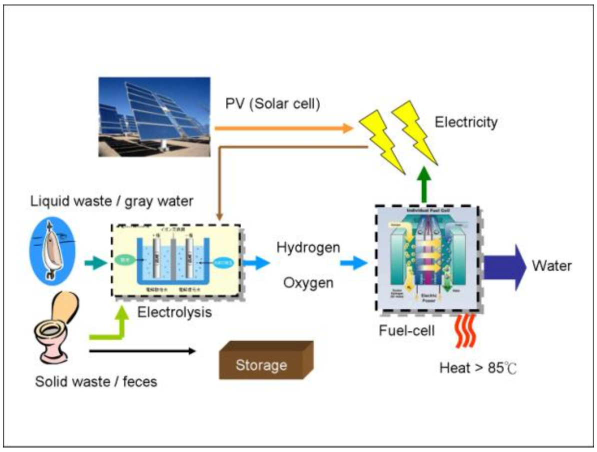



Figure 6. System concept of S-RRV

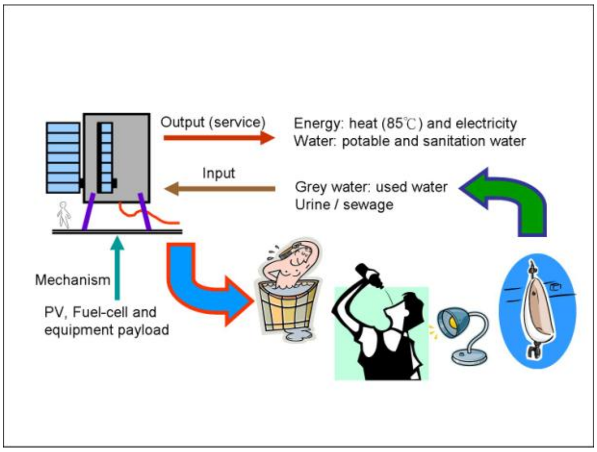



Figure 7. System scheme of S-RRV

Figure 8. Image of S-RRV deployment

For other onboard mechanics or devices can be considered such as: manual or automatic navigation, control mechanics, initial gyro, retro rockets, parachute, TPS (Thermal Protection System), heat shield or inflatable ones, landing gears, etc.

A fleet that consists of one C-RRV and one S-RRV is the basic transporting group for a launch.

Figure 9. Image of overall service sequence


Figure 10. Combination of single launch

**3.3.3 Launch facility section**

The launch facility should include the following properties: 1. Secured place, 2. Robust context, 3. Near airport or harbor, 4. Easy to collect stuff, 5. Allows technicians or trained personnel for constantly standby.

Recent research of sub-orbital transportation that had done by US army discussed concepts of designing a capsule for sending troopers to front zone in war time. It is also pointed out some disadvantages such as it would be traced by infrared signature during reentry phase, armor and weight trade-off, returning and refuel problem, etc.

The proposal in this paper, however, studies recent massive disasters (mainly earthquakes) and problems of current emergency supply transportation concluded that conventional transportation method will consequently meet its limit under much more challenging condition of future complex disasters. Once the RRVs reached the destination, they keep providing service until local force set in or cooperate with these RRVs as essential resource for local rescue. After supporting period ends, the RRVs can be recovered by certain ways and for maintenance.

RRVs provide early support and hygiene management in stricken areas help to prevent people from secondary disaster which may caused by disease or poor waste control.

**3.4 Other options that meet various cost needs**

**3.4.1 Mass driver**

Mass driver is an enormous facility that applies a long rail and accelerates spacecraft to a speed of 7.9km/s by using electromagnetic filed or rocket to planet's low orbit or beyond. It is considered to be a relatively cheap way to launch spacecraft from the surface of Moon or Mars, but on Earth is not appropriate by its huge gravity. However, sub-orbital transportation involves lower speed than to reach LEO and may be a possible way to launch RRVs.

Figure 11. Mass driver
(Courtesy of LaunchPoint Technologies Inc.)

**3.4.2 Discharged and derived ICBM rockets**

Although many ICBMs were discharged after New START (New Strategic Arms Reduction Treaty) rockets are still functional in certain manner. Derived ICBM rockets such as Atlas, Taurus or Titan rocket family, they can be transferred into commercial use to launch satellites or other tasks like international emergency response cooperation. Also, launch complex or silo provides good shelter from being damaged by spread out massive disasters (e.g. asteroid impact).

## 4. Conclusion

Despite many researches of military sub-orbital transportation or commercial sub-orbital flight/tour have been conducted, this research suggests that a potential field of sub-orbital emergency transportation in worst cases for procuring essential supplies in isolated stricken areas and provides a review of preliminary status. Following steps may be collaborations and to intrigue interests among related industries or personnel to seek out the further foreseeable realization. Future issues includes: 1. Emergency response regulation supplements by utilizing sub-orbital transportation solution, 2. Assessment and evaluation methodology (e.g. SWOT or PEST), 3. Quantification and reliability validation plan, 4. RRV recovery sequence 5. Possible manned RRV development, 6. Research roadmap and check point.

## Acknowledgement

The author would like to give his deepest appreciation to partners and supervisors of the interuniversity space architecture research group: Consortium of Extreme and Space Settlements, CESS for contributing their precious effort and time for promoting and educating the space enthusiasts.

Also, I would like to give my gratitude to my research partner Chun-Chien Wang of Geomatics Laboratory of National Taipei University of Technology.

This research is looking forward to deriving aerospace technologies to contribute to a solution making for problems of emergency logistics and stimulating local revitalization during massive crisis circumstances.

*"It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow."* --- Robert H. Goddard

## Reference

1) Huai-Chien (Bill) Chang, "UP with Hope", Talk in TEDxTokyo 2012 event– Where Art Meets Science, June 30th, Hikarie, Shibuya, Tokyo, Japan. *http://tedxtokyo.com/en/tedxtokyo-2012/speakers/huai-chien-chang/*
2) Taylor Dinerman, "Point-to-point suborbital spaceflight and military logistics", The Space Review, *http://www.thespacereview.com/article/1103/1*
3) David Hoerr, "Point-to-point suborbital transportation: sounds good on paper, but…", The Space Review, *http://www.thespacereview.com/article/1118/1*
4) Simon Adebola et, al. "Great Expectations: An Assessment of the Potential for Suborbital Transportation", Masters 2008 final report, International Space University.
5) 青木節子国際宇宙法研究会, 「弾道飛行への現行宇宙諸条約の適用可能性」, *httpspacelaw.sfc.keio.ac.jpsitedevarchiveorf2005.pdf#search=%27%E5%BC%BE%E9%81%93%E9%A3%9B%E8%A1%8C%E3%81%B8%E3%81%AE%E7%8F%BE%E8%A1%8C%E5%AE%87%E5%AE%99%E8%AB%B8%E6%9D%A1%E7%B4%84%E3%81%AE%E9%81%A9%E7%94%A8%E5%8F%AF%E8%83%BD%E6%80%A7%27*
6) Satellite Launch Ring, LaunchPoint Technologies Inc, *www.launchpnt.com*
7) Justin Fitzgerald, "Fuel Cells: A Better Energy Source for Earth and Space", *www.nasa.gov/centers/glenn/technology/fuel_cells.html*
8) NASA Glenn Research Center, "Space Power Systems Project – Regenerative Fuel Cell Technology Development", https://electrochemistry.grc.nasa.gov/main/current-project/etdd/space-power-systems-project-regenerative-fuel-cell-technology-deparment
9) NASA Technical Reports Server (NTRS), "Hydrogen-oxygen electrolytic regenerative fuel cells", *http://naca.larc.nasa.gov/search.jsp?R=19690009547&qs=N%3D4294129240%26Nn%3D4294966819%257CDocument%2BType%257CPreprint*
10) Consortium of Extreme and Space Settlements (CESS), *www.cess.asia*
11) Huai-Chien (Bill) Chang, 「弾道飛行を用いた大規模災害時の僻地等へ救援物資の2地点間運輸システムの実現に関する研究」, 第56回宇宙科学技術連合会議, *http://www.jsass.or.jp/spnavcom/56ukaren/*
12) SURVIVAL®FOODS, *http://www.sei-inc.co.jp/lineup/half.html#cs*