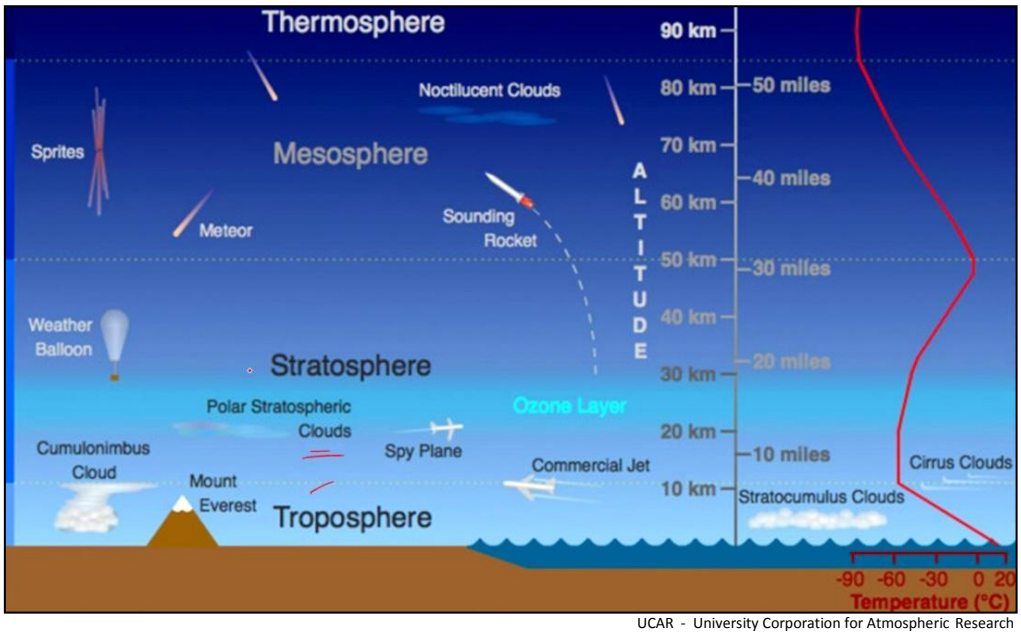
The "OXYGEN" Airlift:

Feasibility & Base Engineering Discussion Paper.

Delivery Engineering Addendum.



UCAR - University Corporation for Atmospheric Research

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D. D'Arcy-Evans

Project Director & Chief Technical Officer (CTO)
Green Carbon Recovery (UK) Ltd.
don.darcyevans@gmail.com
https://greencarbonrecovery.com/

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Abstract:

In my last paper I alluded to the feasibility of the Oxygen Airlift - & yes - it's possible & affordable.

However, the scale of the GHG *(Green House Gas)* problem may mean:

- The execution may need to be quicker & possibly repeatable, or even on-going;
- A more diverse delivery & spread of resources may be needed to accomplish that.

A recent UK newspaper article *(Daily Mail 27 Oct. 2018 - page 57)* has again reminded me that Technoogy doesn't stand still & that Engineering is Art & can achieve ''elegance''.
The caveats being:

- The definition of Capital that is applied; &
- The number of variables any solution satisfies -
  (apart from the manditory & crass ''how quick / how cheap'').

Why do we need to consider another delivery method ?? *(apart from - ''because we can'')*

- The release of Arctic Methane from melting Icecaps & Permafrost may now pose a more pressing & imminent problem for Global Warming than CO2, than previously estimated.

- The O_2 airlift may have to be executed much quicker, & over a longer project time-line as a result, as there are now other variables & outcomes to balance.

- The amount of O_2 delivery will have to be greater and needs to embrace a multi-delivery scenario to properly balance Outcomes with Engineering, Logistics & Cost.

Overview:

Some of the conclusions in my last Paper were not entirely expected.

- It appeared that an Aviation solution to deliver bulk O_2 was probably the best after all *(the B2 Bomber option)*; &
- The other critical path item was the scale of the O_2 production required.

In general;

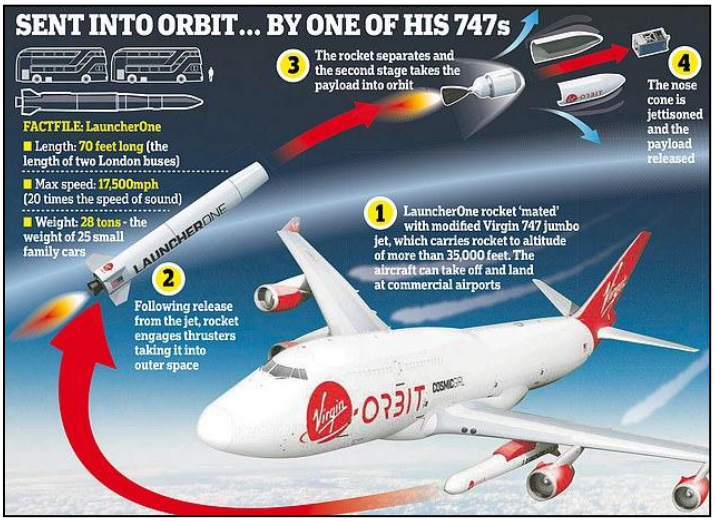
- Cost was manageable at *c.* 18 ..... call it us$ 20 Bn.
- Fast-tracked: A one-off Project/Solution *(6,000,000 tonnes of O_2)* can be completed in around 8 years. *(after around 5 years of mobilization).*

Since then, I have had some more thoughts:

- An adaption to the Space Elevator (tether) system & Balloon Tube ideas: A tube from Space to suck CO_2 out instead of getting O_2 up.
  a) This was based on Italy/US experiments in the 90's conducted with a reel deployed from Space into the upper Atmosphere.
  b) The limiting factors here were:
     - The thin gases at mid-Atmosphere,
     - The tube would have to go to Surface to get best volumes & concentrations,
     - Then there was the separation of GHG's from the existing Ozone to consider.
  c) Then there were visions of Dry Icebergs in Space - possibly very big ones - & visions of a high speed Titanic like event with the ISS. *(anyway - you heard it here 1st folks in case Hollywood wants to take advantage)*.

- Missile Technology was revisited. *(In light of new publicity & gains made by Richard Branson & LauncherOne).*

  Only this time, it's conventional Aircraft, from service altitudes to the Stratosphere & not into Space.



The Concept:

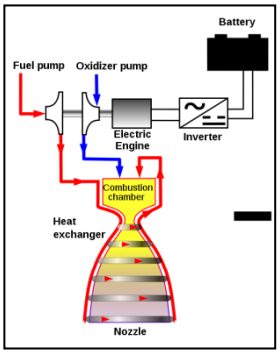
The Aircraft: Boeing 747

- Available in large numbers - 1547 units delivered
- Long reliable service life.
- Still in production.
- Relatively Cheap *(average new cost us$ 83 Mill.)*.
- Service ceiling: optimum flying altitudes 35,000 - 40,000 ft. (10.66 - 12.2 km)
- Normal average payload - 112 tonnes. (Using only 40% of the average fuel load of 200 t - the total effective payload could be - 272 tonnes. *(Does anyone remember the old anecdote about the B-17; "1 mile with a 1,000 lb bomb, 1,000 miles with a 1 lb bomb". No I'm not that old; these sayings are enduring. So to go "the whole 9 yards" on this for instance - would be the length of the .50 cal. belt on the B-17's guns).*

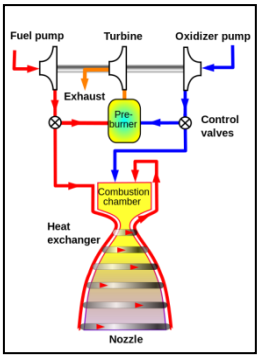
The Rocket:

- Launch altitude - 11kms (36,250 ft)
- Delivery Altitude - 17 to 20 kms
- Needs to gain another - 8 kms / 26,500 ft in altitude from launch point to release point.
- Standard Liquid Oxygen motors.
  There are a number of newgen LOX motors in current use - eg.

Rutherford Motor.



Merlin Motor.



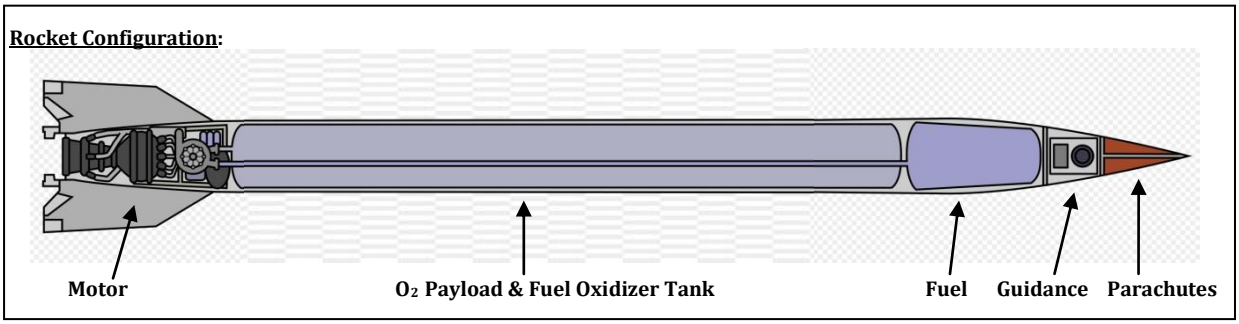
Russian RD-180 Motor.
(Kerosene - known Muscle Motor)

- Re-usable - (*eg.* Rocket has to parachute to Ground, or be self-landing like Musk's Space X).

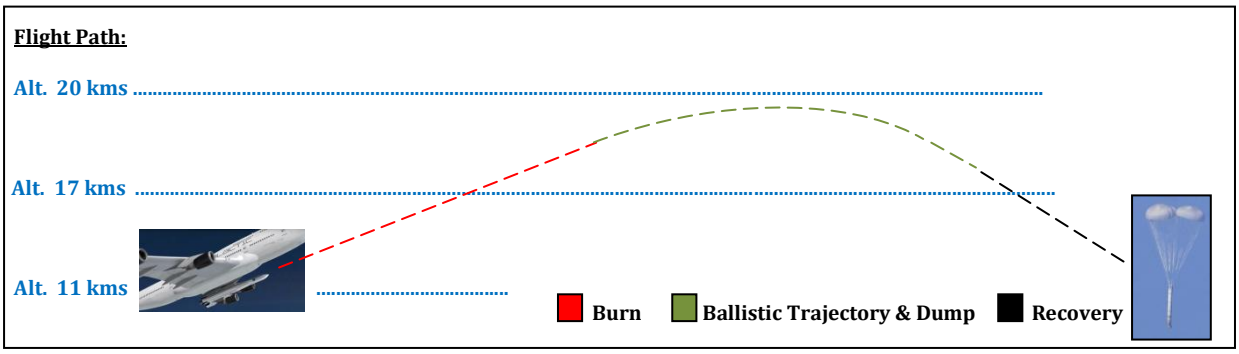
The Flight Concept: (similar to the X-15 program)

- The concept is that it's a simple rocket with no 2nd stage, or payload.
  - Just a massive Liquid Oxygen Tank with a much smaller Fuel Tank.
  - The motor burns sufficiently to get the Rocket to target altitude & turns off leaving the Rocket on a stable, but decaying (ballistic) arc trajectory.
  - The Oxygen is dumped (via the still operating Oxidizer Pumps &/or Dump Jets designed to act as thrusters) before the Rocket's trajectory regains the 17kms altitude mark.

Rocket Configuration:

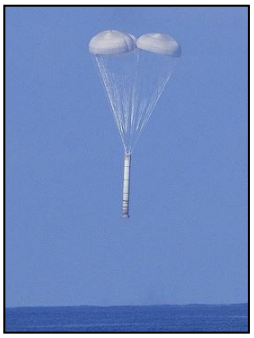


Flight Path:

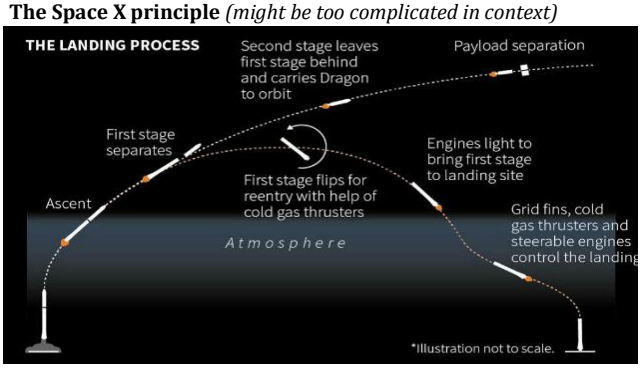


- The empty Rocket either continues to fall & deploys Parachutes (& possibly airbags to cushion ground impact as does the Mars probes), or returns to Earth under its own Power as does Space X. *(some Oxygen has to be retained as fuel if that is the case).*

Parachute Recovery examples



The Space X principle *(might be too complicated in context)*



- For those who remember the X-15: It was a manned vehicle, but with the tech. of today, a Drone capability could be engineered into the Rocket so it could self land as did the X-15.

- In any case - the Rocket is reused.

Logistics:

The B-747 capacity & suitability.

- The X-15 & LaucherOne Rockets are wing mounts, so there will be a weight restriction for the hard points, unless the mounts are also incorporated into the Fuselage super-structure.
- With a 40% fuel load to take off, get to altitude & launch & then land - it is possible to have a payload of around 270 tonnes - It should be possible to mount 2 x Rockets of approx. 135 tonnes gross systems weight each.
- Can operate from Commercial Airports.
- Over 1500 planes have been built so getting numbers between 100 & 200 should not be a problem, quickly & cheaply, for emergency, or fast-tracked deployment. *(long hours Freighter conversions,* - Certainly quicker than the B-2 proposal & is vastly greater numbers.

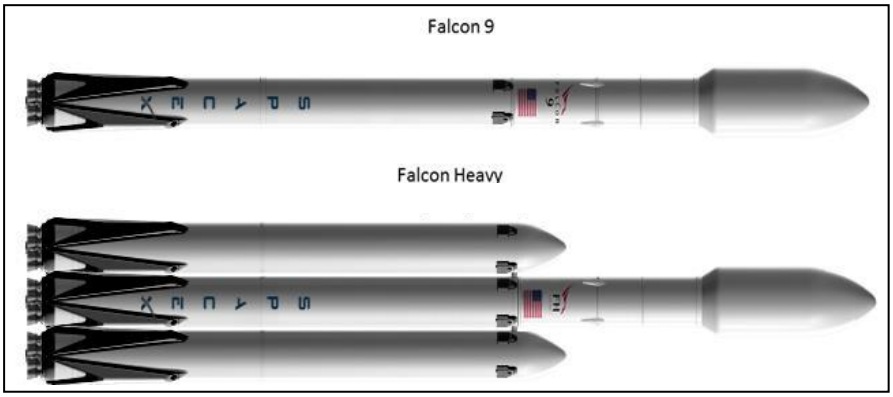
The Virgin Orbit 'LauncherOne' Rocket. *(Limited Specs available)*

- Dimensions: 70 ft lth. /
  Stage 1 & 2 dia: 1.62m - 1.27m
  Wt: 25.4 tonnes. (28 tons)
- Kerosene - LOX motors.
- The X-15 has a rate of climb of 18.2 kms/min. - The Rocket has to achieve approx. 8 kms extra altitude under power - This will require 25 - 30 secs. of burn - the 1st stage of the rocket has a burn time of 180 secs.
- Approx. 84% of design 1st Stage onboard O_2 would remain for delivery.

- All of 2nd Stage weight *(except for fuselage shell & on-board systems)* is available for O_2 payload.
- Expected payload after design modifications: <u>20 tonnes</u> each Rocket x 2 = <u>40 tonnes</u> per a/c sortie. *(B-2 option - 60 t).*
- From the cut-away at right, it can be seen that the LauncherOne rocket has large existing capacity for extra O_2 tankage & other required modifications.
- It is possible that the gross weight of the unit may also be increased some (within the same dimensions) to increase O_2 payload.

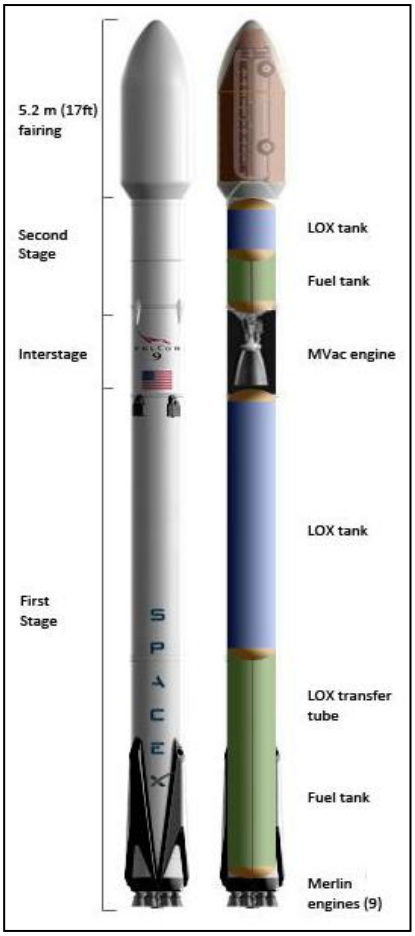
The Space X Falcon 9 Rocket.

Space X has 2 vehicles available - the <u>Falcon 9 FT Block 5</u> & the <u>Falcon Heavy</u>.



Specs. available are scant, but the Vital Stats., as can be worked out, shape up thus in the table below:

	Falcon 9	Falcon Heavy
Height	70m (230 ft)	70m (230 ft)
Diameter	3.66m (12 ft)	12.2 m (40 ft)
Take-off Weight	549t (1.2 mill. lbs)	1,421t (3.13 mill. lbs)
est. Dry Wt.	32t	86t
payload wt to LEO	22.8 t (50,265 lbs)	26.7 t (58,900 lbs)
est. Propellent wt.	410 t + 84t = 494t	1230 t + 78t = 1308t
fuel to LOX ratio	2.3	2.3
1st Stage burn time	162 secs - 70kms	187 secs - 100 kms
Burn time to Altitude	85 secs - 18 kms	90 secs - 18 kms
% Fuel burn to Altitude	52	48
% av. Fuel burn to land	10	10
Flight turn-around	1 day (target for 2019)	1 day
Best Case - Parachute recovery all round - no powered landings.		
est. LOX payload	**342t**	**515t**



- These units are too large for Aircraft delivery, so they will have to be deployed on a modified Flight plan of their existing use.
- The same design applies as for the LauncherOne unit.
  a) No 2nd Stage, just a bulk O_2 tank.
  b) Short burn to target altitude, arced ballistic dump trajectory & return to Earth.
- The initial issue is KISS, so parachute recovery has to be the go so max. O_2 is delivered.
- There are currently only about 5 launch facilities available & they are North American.
- The 1 day turn-around is a Space X target for 2019, but even 2 days would be significant in terms of unit availability.

Execution Planning.

When looking at the 2 missile options, let's first start with what deployment is possible in each case. After all the prime aim is to see how quickly the Global Warming problem can be addressed.

Virgin Orbit LauncherOne - Base Case:

- 100 x B-747 aircraft with 2 x missiles on each.
- 5 x 4 hr Sorties /day for each aircraft x 6 days/week.
- With 2 day turn-around on the Missiles & 5 Sortie /day = 20 Missiles are required for each Aircraft ..... 2,000 Missiles minimum are required for the program
  (30 Sorties/week - over 312 day p.a.) = 1560 Sorties x 40t/Sortie = 62,400t / aircraft p.a.
  100 aircraft x 62,400t = 6,240,000 tonnes p.a. - *target delivery - 6,000,000 t*

Delivery Time: 1 year.

Space X - Base Case:

Falcon 9:

- Payload - 342t / flight
- 320 operating days p.a. x 1 flight every 2 days = 160 flights
  (160 x 342t = 54,720t p.a.) - 6,000,000 / 54,720 = 109.7 years *

Falcon Heavy:

- Payload - 515t / flight
- 320 operating days p.a. x 1 flight every 2 days = 160 flights
  (160 x 515t = 82,400t p.a.) - 6,000,000 / 82,400 = 72.8 years *

* *If the turn-around comes down to 1 day - the time frame halves - (55 & 36.5 years respectively). If multiple launch pads & more than 1 rocket set is used, more launches are possible & the time frames keep halving to practical deliver times.*

Based purely on Rocket cost, the most practical option in context here is obviously: LauncherOne.

O_2 Production Issues.

O2 production is still the critical path both for location & size of production, just as it was with the B-2 option discussed in the previous document.

As such, the only test case to be investigated here will be LauncherOne. *(O_2 demand is higher)*

Oxygen Requirement:

- 20 Missiles x 20t ea. of O_2 = 400t /day for each Aircraft.
- 100 Aircraft x 400t /day = 40,000 tonnes O_2 /day production required to meet program.

Oxygen Production Realities:

From the analysis in my previous document, we will presume Air Separation as the most viable method of O2 production.

- World production of O_2 is 1,700,000 tonnes/day.
- 40,000 tonnes/day = 2.4% of that.
- Largest Air Separation Plant - 5,800 tonne/day. *(SASOL, South Africa)*
- 8 x such plants required to meet the Missile Program.

Existing Production:

For immediate results to support an accelerated delivery Program, purchased Oxygen from the existing sources should be possible before the 8 x new & dedicated production is on line.

This is logistically feasible as delivery would be by commercial Aircraft operating from existing Airports located near to the existing O_2 production.

This may, decrease the number of the 8 x new O_2 Plants. - No analysis concluded herein.

Cost:

Aircraft:

- 100 x older converted B-747 @ average cost ..... us$ 50,000,000
  (fully inclusive delivery cost to OPEX)
  ..... **us$ 5,000,000,000**

Missiles:

- Virgin Orbit LauncherOne
  Book Price for as designed *(into space delivery)* - Not available.
  (but let's presume that the Unit cost is within reach, as it's a commercial development, & that a major part of that cost must be covered in the Launch cost).

  Airlift Stratosphere Convention: Must bring the unit cost down.
  2,000 Missiles @ (assumed) $5,000,000 ea ..... **us$ 10,000,000,000**

- Space X - Falcon 9
  Book Price for as designed *(into space delivery)* - Not available.
  (but let's presume that the Unit cost is within reach, as it's a commercial development, & that a major part of that cost must be covered in the Launch cost).

  Airlift Stratosphere Convention:
  Must bring the unit cost down. If LauncherOne can be guess-timated at $5,000,000 apiece, then Falcon 9 has to be around the same.
  The Falcon Heavy, as it is essentially 3 x falcon 9 boosters would be *c.* us$ 15,000,000

Operations:

- Virgin Orbit LauncherOne
  (The current commercial cost into space is 10 - 12 million per unit).
  est. Cost for 2 x missiles per Aircraft ..... us$ 10,000,000
  Aircraft Sortie Cost (all in cost) ..... us$ 300,000 *(5 hrs x $ 60,000 /hr)*
  Program Cost: 1560 sorties x 100 a/c *(for 6 million Tonnes)* = 156,000 sorties
  ..... us$ 1,606,800,000,000

  (Cost of LauncherOne is well in excess of 1.6 trillion even if it is operationally achievable in 1 year. - 3 x the current annual US Defence Budget.
  (This becomes more manageable if individual flight costs could be reduced 50% or more).
  LauncherOne is a quick Solution, but at a price.

- Space X - Falcon 9
  (The current commercial cost into space is $ 60 million per unit - Falcon Heavy is $ 90 million per unit).
  est. Cost per Flight ..... us$ 30,000,000
  est. Falcon Heavy ..... us$ 45,000,000
  Minimum Program Cost for 1 year - 160 flights ..... us$ 4,800,000,000

  (Cost of Space X is out of the question due to the long program time, without the currently unknown production cost of the base vehicle).

Space Ship One - Tier One Program.

Another Technology should be mentioned. It's similar to LauncherOne. It's now retired, & has been discounted as an option on performance grounds *(see characteristics below),* but could be a good low-tech alternative in large numbers if flight costs are reduced.

We mention it here (to be thorough) & because the unit Aircraft costs are potentially very low, as are the Flight costs. The simpler design also improves mobilization lead-time. *(Which is the biggest problem all round for all the Oxygen Airlift Program).*

The problem arises with the limited payload & number of Sorties required. Solving the payload issue would substantially improve the numbers & suitability of this tech.

Although development costs were a reasonable $ 25 million, & flight & base aircraft cost would be quite low (no information available), the payload is small - 2.5 tonnes, but how much of that is the fuel & not cargo is not known. If we presume it's payload - the figures look like this:

eg. (6,000,000 t delivery of O2 = 3,000,000 sorties / 200 aircraft x 5 flight a day = 1,000 flights per day = 3,000 days flying) - 8.2 years best case delivery with 200 aircraft. *(4.1 years with 400 aircraft)*

Unit cost: 5 million x 200 a/c = $ 1,000,000,000

OPEX: $ 333k / flight x 3,000,000 = $ 1,000,000,000,000
(approx. 2 x current US Defence Budget).

White Knight Launch Aircraft

General Characteristics.

Crew: One pilot
Length: 16.4 ft (5 m)

Wingspan: 16.4 ft (5 m)
Height: (n/a)
Wing area: 161.4 ft² (15 m²)

Empty weight: 2,408 lb (1,092 kg)
Loaded weight: 7,920 lb (3,600 kg)
I_{sp}: 250 s (2450 Ns/kg)
Burn time: 80 seconds

Aspect Ratio: 1.6

Powerplant: 1 × N_2O/HTPB SpaceDev Hybrid rocket, 7,500 kgf (74 kN)

Maximum speed: Mach 3.09 (2,170 mph, 3,518 km/h)
Range: 35 nm (40 mi, 65 km)
Service ceiling: 367,360 ft (112,000 m)
Rate of climb: 82,000 ft/min (416.6 m/s)
Wing loading: 49.07 lb/ft² (240 kg/m²)
Thrust/weight: 2.08

SpaceShipOne

SpaceShipTwo (mounted on White Knight 2)

The Virgin Galactic SpaceShipTwo project produced a better option. Developed on Licence from the Tier One Project, the development costs rose to $ 400 million, but so did the Payload.

With a 6 passenger capacity & a reduced operation fuel load requirement, we can assume that the above guess-timation of 2 Tonnes is a reality, thus giving substance to the possibilities of this craft being a suitable technology - especially if it is a Drone capable vehicle instead of a manned unit.

Conclusions:

Regarding the Delivery:

- There are a number of Delivery techs. & options available.
- With varying cost-benefit profiles.
- But Oxygen may not be the only possible Cargo.

As we are discussing new information - there is another interesting article on the subject recently available - this involves Airlifting Sulphates into the Stratosphere as a blanket - (similar to what the ash clouds from active Volcanoes do when they erupt).

https://www.nextbigfuture.com/2018/11/100-special-planes-and-2-5-billion-per-year-for-sulphate-geoengineering.html

Comments:

I would question the numbers put forward in the Article - A ramped Program is suggested with only the low estimate cited.

The over-all Program spec is clear, & in that case the numbers stack up as below & not as they are presented in the article's headline.

There is a good reason for doing their full program ASAP because when achieved as the slower approach, it will take a much longer time period to quantify results. Time we may not have.

The Proposed Program:

- 100 Specially designed new Aircraft.
- Program Delivery: 5,000,000 tonnes p.a.
- Aircraft Development costs *(3 models offered):*
  - McClennan Study ..... us$ 2.1 - 5.6 Billion
  - SAG (TU Delft) ..... us$ 14 Billion
  - SAIL ..... us$ 2.35 Billion
- Payload: 20 tonnes.
- Flights: 250,000 p.a. *(7 flights / day / Aircraft - Flight turn-around: 3.4 hrs)*
- Delivery Cost: us$ 1500 / Tonne..... us$ 7.5 Billion p.a. *(not 2.5 Billion)*

- Continuous operations on an on-going basis to limit the effects of Warming, not to solve the root causes - it's a containment exercise.

The Problem & the Approach.

It would perhaps be useful at this point to take a 30,000 ft view combining the information from both the current & my previous Document.

- We want to halt Global Warming.
- We need to do it quickly - 10 years max.
- A solution is possible.
- We can afford it *(we have to)*.
- We have 2 scenarios on the table:
  a) Containment with Sulphates, &
  b) Mitigation with Oxygen.
- Containment requires an Airlift solution.
- Mitigation requires an Airlift Solution, but could also have a Surface solution. *(see below).*
- Mitigation Airlift options:
  a) Balloon Array *(with O2 pumped from Surface)*
  b) Converted Military Aircraft *(best case - the B-2 Bomber).*

c) Special Purpose Aircraft design. *(several options available).*
d) Converted Commercial Aircraft with a Missile delivery system.
e) Surface launched Missiles.

- Mitigation Surface option.
  a) Monatomic Oxygen production to specifically address Arctic Methane releases.

Critical Path Items:

- Aircraft Development & Production Lead Time.
- Missile Production Lead Time *(if that solution is required).*
- Monatomic Oxygen Production & Equipment Lead time.
- Oxygen Production & Equipment Lead Time.
- Sulphate Reagent Production & Equipment Lead Time.
- *(Political factors not considered to be a Critical Path Item as they are a matter of will, not practicality - they can do it if they want to).*

Structural Issues in the Approach:

The glaring issue that presents to me is how any of these programs are quantified & monitored.

- An Oxygen airlift will likely deal with the upper atmosphere issues with GHG's & Ozone depletion. *(as it is a copy of previous natural phenomena - Snowball Earth).*
- A quick delivery of 6,000,000 tonnes over 1-2 years is possible with a pause for evaluation.
- Any repeat can quickly follow.

However;

- If the Sulphate blanket is also applied at the same time, how do we properly evaluate things.
- To my mind it has to be 1 or the other, and a cure is always preferred to a band-aid.

Then we have an increasing and yet to be fully determined Arctic Methane situation emerging.

- This will likely skew the Airlift figures anyway.
- The Methane problem also has to tackled ASAP, or the other measures may not have any effect & containment of its data contaminating effects seems desirable if it helps preserve a 'status quo' to which other things are measured.
- So, it is probably best to concurrently conduct both the Airlift and a membrane generated Monatomic Oxygen Surface Release Program for Arctic Methane.
- Separate monitoring of reasonable reliability should still be possible on both Programs with similarly reliable extrapolation of the combined results.

Blanket remedies should thus be postponed a few years until we know what's going on, or until we are truly 'screwed' and have to use them.

- In any event, we would need a dual Airlift Program to achieve the Blanket Remedy anyway, so that resource, if economically justified, could enhance the original Program & then be deployed to a Blanket remedy later if required. *(etc. etc.)*

Then we also have to address the existing issues regarding the Environment:

They can't be left to slide, or procrastinated upon as is the current Political trend & practice.

- I am not a great fan of Green Politics. They have very little to do with the environment and everything to do with Globalism & grabbing Political Power.
  (I've never understood Globalism. Nobody does what they are told, & usually get violently upset when they are forced to do things they don't want to do - yet like Lemmings, they are keen to rush headlong into the centralized irreversible Autocracy currently presented to us as Globalism. Freedom is about Choice. Democracy is a Co-operative & about Consensus. The Globalism on offer to us politically is about neither).
- The politics are a true shame, & they have a name - **"Green Washing"**
- Green-Washing aside, there is a problem, even if we can't agree on the science.

- The problem requires action & at least, that action should be simply from the non-political point of view of stopping the Littering. That is law most places anyway.
- So something has to be done & is morally and practically required without even having to go anywhere near the dodgy politics - And we have to do it - And that can be done without engaging any other agenda than just the desire to fix the Litter.

- Anything else in comparison is then easily seen for what it is and can be avoided and disempowered, if that's what you want to do, as we get on with the job.
- This means that in the end, as the current politics is at very least unreliable, there will have to be Grass Roots & very possibly Commercially driven responses to get things moving.
- The best maintained Highway on the Plant is the road to Hell, as its paving is continually & unnecessarily upgraded with good intentions, rather than positive action*. (not the Hells in Broxbourne UK, Michigan, Grand Cayman, Norway, California, or Slovenia either).*

What has to, & can be done?

- People Power is already getting behind Litter with things like Plastic and Oceans, but more has to be done.
- Emissions are also Litter! The Tech exists to mitigate emissions. *(our Company Green Carbon Recovery specializes in ZERO emissions technology).*
- Green Conventional Power is also possible with Fuel-from-Emissions Technologies *(also a specialization of GCR).*
- This enables CCU *(Carbon Capture & Utilization)* to take place preventing up to 90% of new Fossil Fuel entering the Carbon Cycle as the fuel used is made from recycled reclaimed 'emissions' Carbon, which goes around in a circle.
- The grand vision here is a cleaner majority ''green'' Electric interim future that also avoids Natural Gas in the Power cycle. *(An Electric Society like they have in Norway for instance).*

The Solution.

The bottom line here is that we have to keep on with limiting the current pollution & increasing Sustainability, in conjunction with other Oxygen based remediation *(to mitigate the Industrial Age Carbon we have released from its pre-historic storage in Fossil Fuels).*

Politicians have no mandate to ignore this. Neither do we as individuals, nor can we continue to be sucked in by Politicians & their petty BS.

- There is a problem, regardless of agreement or disagreement of the facts.
- There are affordable practical Solutions.
- Politics doesn't necessarily have to have anything to do with solving it.
- Any Program applying Solutions has to be vertically integrated & Sustainable; & has to be a multi-technology approach; and the Approach has to be organized.
- Time is of the essence & there are safe things we can do until a clearer picture emerges & before we unintentionally run ourselves out of time.

If you have got this far - thank you for your consideration - & hopefully, I have provided food-for-though & we can get some buzz going on these issues & create some of the needed change to guarantee our future. BR DDE

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