

**Methane Moment:
High Level Chemistry,
Toxicology, Environmental
Effects & Dispersal**

What This Decks Contains

- This is the first of seven high level overviews of the proposal:
 - [Chemistry, Toxicology, Environmental Effects and Dispersal](#)
 - [Governance](#)
 - [Operational Data and Security](#)
 - [Costs Overview](#)
 - [Methane Moment & Politics](#)
 - [Program/Project Plan](#)
 - [Background Story](#)
- This one contains:
 - High-level description of the chemistry, toxicology, environmental effects and dispersal for each process proposed

Methane Moment Pitch Package

This deck is part of a Methane Moment package:

- [Website](#)
- [Methane Moment Pitch deck](#)
- **High Level Summary Decks:**
 - [Chemistry, Toxicology, Environmental Effects & Dispersal](#)
 - [Governance](#)
 - [Operational Data & Security](#)
 - [Cost Overview](#)
 - [Methane Moment & Politics](#)
 - [Program/Project Plan](#)
 - [Background Story](#)
- [Reference Document](#)
- [Methane Moment Cost Estimates](#)

TOA-EDARA

- It's used to address methane bursts in the arctic
- It "oxidizes" the methane to carbon dioxide and water

It Begins in Two Tanks and a Hopper in a Aircraft...

Tank 1: Contains liquid Titanium TetraChloride (TiCl_4) and Silicon TetraChloride (SiCl_4)

Tank 2: Contains liquid Nitric acid (HNO_3)

Hopper: Contains powder Aluminum Chloride (AlCl_3)

Mixing in the Air...

- The two liquids and the powder are released after evaporation together, mixing with the outside air of the aircraft
- The contact with water vapor in the air creates very small particles (about 100 nanometers)
- On each tiny particle is created a small coat of a chemical which is extremely diluted aqua regia
- Sunlight acts on the aqua regia to free up chlorine atoms
- Each chlorine atom depletes a methane molecule
- The chlorine atom then returns as hydrogen chloride vapor condensate to the particle
- It can then be used again
- **Bottom line – 1 chlorine atom hypothetically can oxidize/remove 1000 methane molecules**

So What Does the Name TOA-EDARA Mean?

- The particle is Titanium Dioxide (TO)
- A is the aerosol
- EDARA is “Extremely Diluted Aqua Regia Aerosol”

Is TOA-EDARA Harmful To People On the Ground?

- It's NOT harmful the way it's used– why?
- The concentrations on the ground are VERY LOW
- Which is what the next slide's toxicology table shows

TOA-EDARA Toxicology

Chemicals	Type of storage/dispersal				OSHA Standards (Exposure limits)
	Dispersal tank / hopper maintenance	Vapour released from pipe	Aerosol cloud after forming in the air	Ground effects of aerosol[1]	
	mg/m ³				
TiCl ₄	Caution[2]	Keep away[3]	0	0	5[4]
SiCl ₄	Caution	Keep away	0	0	5ppm[5]
AlCl ₃ [6]	Caution	Keep away	0.0014	0.00014	2
EDARA Coat					
HNO ₃	Caution	Keep away	0.0079	0.0032	5
HCl[7]	n/a	n/a	0.014	0.0010	7
H ₂ SO ₄ [8]	n/a	n/a	0.0001[9]	0.0001	1
TOA particle					
TiO ₂	n/a	n/a	0.0014	0.00014	15
SiO ₂	n/a	n/a	0.0018	0.00018	6[10]
AlCl ₃	Copied from above:		0.0014	0.00014	2

Table Footnotes

1. In the air at ground level. Worst case this could be the same as the cloud or haze in the air, which drops to ground level.
2. For cells marked “Caution” standard safety handling procedures must be followed, with recommended protective clothing worn. (The airborne concentrations will vary greatly from inside the tank or hopper to standing close by).
3. Cells marked “Keep away” are for 200°C highly reactive vapor emissions. Protective clothing will of no use in this situation, and direct inhalation of the vapor may be fatal.
4. ERPG-1 (Emergency Response Planning Guideline)
https://cefic.org/app/uploads/2018/12/TiCl4-Safety-Advice-8th-Edition_March-2012.pdf
5. <https://nj.gov/health/eoh/rtkweb/documents/fs/1666.pdf>
6. Solid powder or grains. Stable under normal conditions.
7. No HCl is released. It is an educt of the hydrolysis reaction.

TOA-EDARA Dispersal

- The actual feedstock of the chemicals used in the tank and the hopper are low
- **What's expensive is the aircraft delivery systems containing the chemicals, plus the distances they'll have to travel across the arctic to disperse**
 - Refer to the MEWRS worksheet in [Methane Moment Cost Estimates spreadsheet](#)
- Costs could easily range from hundreds of millions to billions of dollars to disperse the chemicals
- **Which is why the proposal calls for out of the box thinking to create a suite of delivery vehicles which can be used as and when it's cost-effective**

Out of the Box Thinking Re Aircraft Dispersal

- Automated planes
- Automated drones
- Automated hovering drones
- Containers located on the ground near the methane burst which allows drones to land on, refuel and restock their chemicals
- Airships
- Ships with drones
- Etc.

It Requires Aviation Experts to Rapidly Come Up With Ideas to Prototype Them

- Time is of the essence
- Thus governments should quickly bring together aviation design experts and quickly fund prototype development
- Then quickly POC (proof of concept) and pilot them in the arctic
- See what works, what doesn't work and rapidly adjust

Arctic Cooling – Cloud Whitening & Ice Whitener

- This uses two different techniques to cool arctic ice in strategic areas
- One is a cloud whitener which creates clouds over the area thus cooling the area below
- The other is a non-toxic white mineral with water which is sprayed onto the ice, reflecting sunlight back up from the ice

Cloud Whitener - TOA

- It's the same type of chemical used in TOA-EDARA
- It leverages the water vapor already contained in the air to form clouds
- It does this because TOA is an aerosol of microscopic mineral particles dispersed, in a non-toxic concentration, that seeds the formation of reflective haze or clouds
- This reflects sunshine back out to space, providing a cooling influence
- Thus it provides a safe, cost-effective, cooling mechanism

TOA is Low Toxicity

- Just as in TOA-EDARA the table shows very low toxicity
- Thus, it's a good candidate to use to create clouds to cool critical arctic areas

TOA Dispersal

- Just as in reducing methane via TOA-EDARA, the actual cost of the TOA feedstock is low
- However, the cost of dispersal is high from aircraft
- Thus, out of the box thinking needs to be brought to bear to cost-effectively give governments a suite of tools to use
- Beyond the out of the box ideas presented in earlier slides, it also includes land-based dispersal stations

Ice Whitener – Challenges Over Large Areas Like Greenland, Etc.

- Cost of dispersal must be low
- The whitening chemical must be low toxicity and cost
- **Which is why the proposal suggests white marble dust**

White Marble Dust - Toxicity

- Existing research has found white marble dust to be the best low toxic whitener

Exposure type	Authority	Limit
Marble dust Legal airborne permissible workplace exposure limit (PEL) respirable fraction averaged over an 8-hour work shift	OSHA and NIOSH, 2015	5 mg/m ³
Nanoscale TiO ₂ particles (ACGIH TLV, 8-hour TWA)	OSHA, Washington, (2021) United States Department of Labor	0.2 mg/m ³
Fine scale TiO ₂ particles (ACGIH TLV, 8-hour TWA)	OSHA, Washington, (2021) United States Department of Labor	2.5 mg/m ³
Total TiO ₂ Dust (OSHA PEL, 8-hour TWA)	OSHA, Washington, (2021) United States Department of Labor	15 mg/m ³
Exposure limit for 0.01-10 µm TiO ₂ nano particles	Japan Society for Occupational Health (JSOH) and the NIOSH	300 µg/m ³
Annual PM _{2.5} exposure limit (PM _{2.5} is particles with 2.5 µm diameter)	WHO in 2018	10 µg/m ³
	US EPA	12 µg/m ³
	UK and EU	25 µg/m ³

White Marble Dust Cost & Dispersion

- The cost of white marble dust is low
- However, just as in TOA-EDARA and TOA, the dispersion costs are high
 - Refer to the AICS worksheet in [Methane Moment Cost Estimates](#)
 - **Thus, this too requires the same out of the box thinking described above**
- Another issue is how the whitener is dispersed onto the snow
 - Strong winds can blow the whitener powder away
 - Thus the spreadsheet lays out doing this by a slurry which can instantly freeze onto the ice

Feedstock Ratios, AI & Weather Modeling

- TOA-EDARA, TOA and Ice Whitener all have feedstocks which are used to create the final dispersants
- We suspect that different weather conditions, altitudes the dispersant is released, cloud cover, etc. all interplay together requiring different feedstock ratios
- This is where AI (artificial intelligence) and weather modeling all come into play
- We can see the AI creating models to be used at a particular location altering the feedstock ratios

Feedstock Ratios, AI & Weather Modeling

- Further, we can also see AI, within the delivery vehicles, taking in local data and further refining the dispersal feedstock ratios, rates of dispersal, etc.
- To make this magic work requires rapid R&D, POC's (proof of concepts) and small, controlled pilots to prove all of the above out
- Learn what works, what doesn't work and fine tune delivery dispersant processes
- All of the above must feed into prototype design of out of the box delivery vehicles

Feedstock Ratios Research Examples

- The dispersal rate should be matched to wind speed, to get a specific particle count per cm³ of air
- Dispersal should be turned off when it's raining or snowing, and perhaps even when it's forecast - otherwise, the particles will just get immediately rained/snowed out
- In high humidity conditions less AlCl₃ will be needed to nucleate droplets
- In low humidity conditions perhaps even particle size could be increased up to about 0.5 microns, to encourage nucleation
- When the sky is clear and the sun is strong the Ti content could be increased, to maximise reflectivity
- The reference doc has sections in MEWRS and AICS addressing this

Reduce Methane Levels By Half Over 4-5 Years

- We're proposing over 4-5 years to reduce existing methane levels by half, taking us back to early 1900's levels
- This can be done by using tax credits and subsidies from companies supplying jets, drones, ships with drones, etc.
- It will reduce the temperature rise by 0.21 C
- This might not sound like much, but it effectively buys governments time to work on reducing the CO2 levels
- The next slide shows our rough calculations for this

Reduce Methane Levels By Half Over 4-5 Years

- 1 methane ppm is equivalent to 120 CO₂ at time of release
(<https://pubs.rsc.org/en/content/articlehtml/2018/em/c8em00414e>)
- Existing methane level is 1908 ppb (<https://public.wmo.int/en/media/press-release/more-bad-news-planet-greenhouse-gas-levels-hit-new-highs>)
- So, current CH₄ in terms of CO₂ is $120 * 1.908 \text{ ppm} = 229 \text{ ppm}$
- Current CO₂: 417 ppm (<https://www.co2.earth/daily-co2>)
- Total CO₂ equivalent = $417 + 229 = 647 \text{ ppm}$
- Halving methane is 954 ppb which is .954 ppm
- This is $0.954 * 120 = 114 \text{ ppm}$ in terms of CO₂
- The total CO₂ equivalent of 647 ppm contributes a temp rise of 1.17 C
(<https://unfccc.int/news/united-in-science-we-are-heading-in-the-wrong-direction>)
- $114\text{ppm}/647\text{ppm} = 0.18$
- $0.18 \text{ C} * 1.17 = 0.21 \text{ C}$

Save Critical Human Water Supplies Fed by Mountain Glaciers

- Take the cloud whitener and ice whitener tech proved in the Arctic and apply it to preserve existing critical glaciers which are headwaters for human water supply, agriculture and hydro-electricity
- **The goal is over 2-4 years to significantly reduce the rate of melt of these critical glaciers**

Summary - Innovate, Learn and Leverage

- We're proposing innovating in the Arctic to learn how to safely, cost effectively address methane bursts and rapidly shrinking ice
- Learn what works
- Then scale rapidly to mountain glaciers, and halving methane levels

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