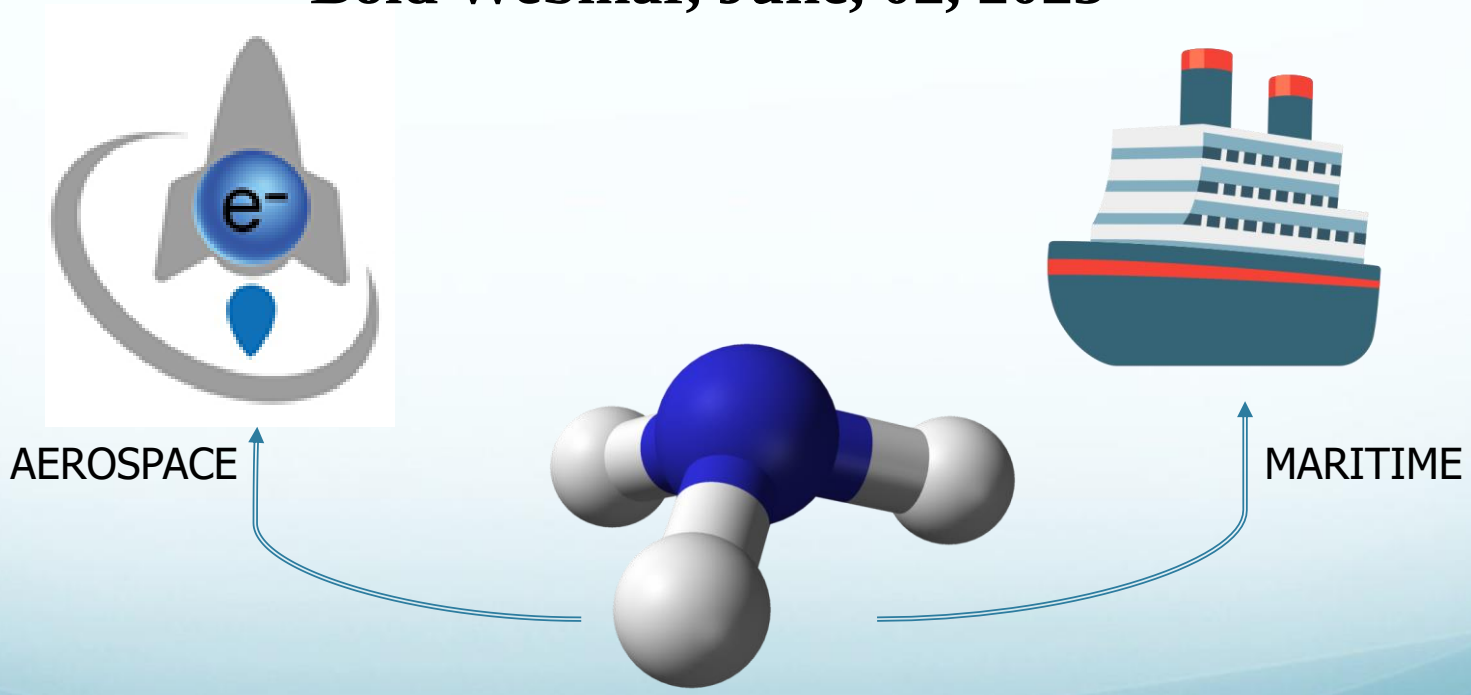
# NH3 cracking and pure H2 extraction

## Bold Webinar, June, 02, 2023



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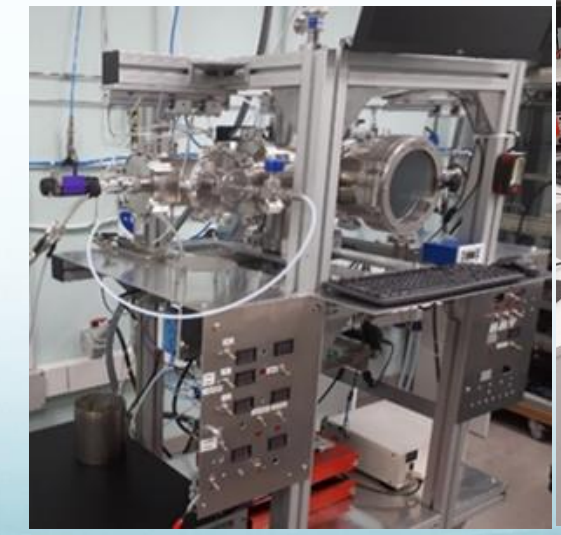
# 1.- ATD presentation. Expertise and facilities.

**ADVANCED THERMAL DEVICES (ATD)**

Technological Spanish SME company initially focused on refractory materials and heat treatments.

During the last seven years there has specialized in electro ceramics, especially for the emission of electrons applied to electric propulsion for the aerospace industry. So, ATD is the NEMESIS project leader (European project ID:870506, https://cordis.europa.eu/project/id/870506).



# 1.- ATD presentation. Recent Projects.

Financiado por la Unión Europea
NextGenerationEU

Plan de Recuperación, Transformación y Resiliencia

GOBIERNO DE ESPAÑA · MINISTERIO DE CIENCIA E INNOVACIÓN · CDTI INNOVACIÓN

HIDRAM

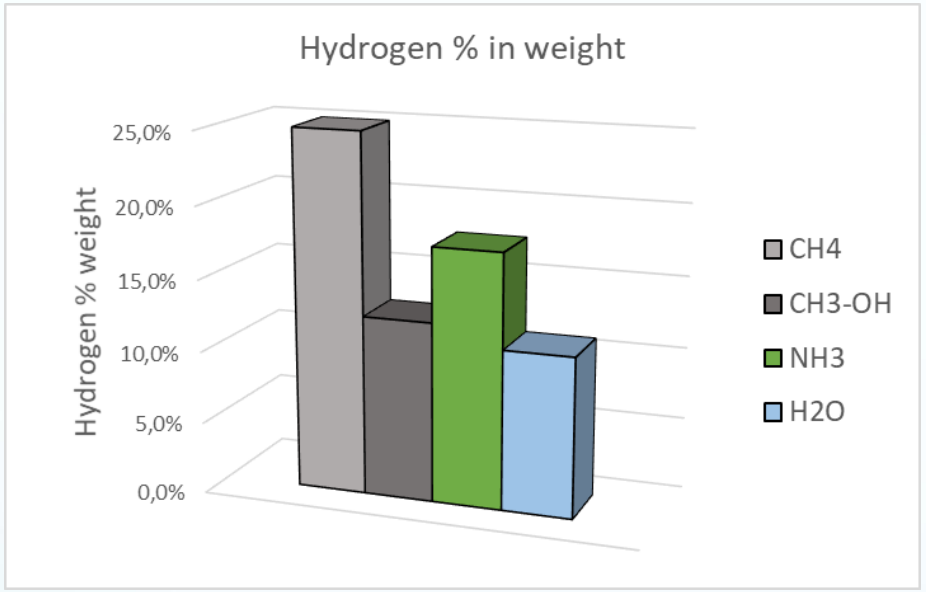
Oct,2022 – Dec,2024. COMPLETE AMMONIA CHAIN.
NH3 Synthesis (No Haber-Bosch. Catalysts reactor).
NH3 Storage and logistics
NH3 cracking on board. Pure H2 extraction:

- H2 PEM FC
- NH3 H-SOFC


Oct,2022 – Dec,2024
Zero emission and high autonomy UAVs
New VTOL concept: plane+dron
H2 PEM FC
NH3 H-SOFC

# 2.- NH3 as H2 molecular packer

**NH3 is the second best molecular H2 packer (behind CH4) and the FIRST Carbon-free H2 packer.**




| | MAXIMUM H2 MOLECULAR PACKAGING | | | |
|---|---|---|---|---|
| | Methane | Methanol | **Ammonia** | **Water** |
| | CH4 | CH3-OH | NH3 | H2O |
| Mol weigh | 16 | 32 | 17 | 18 |
| H weight/mol | 4 | 4 | 3 | 2 |
| %H in weight | **25,0%** | **12,5%** | **17,6%** | **11,1%** |

**1 Kg NH3 (liquid)** = 1.6 L at 10bar@25ºC or 1 bar@-33ºC.

**1 Kg NH3 contains 176 gr H2** or 5,88 KWh energy in terms of H2

**1 Kg NH3 (liq) (1.6L) has around 850 compression ratio vs. gas**, that means. That means an energy density higher than the same volume of 700bar H2, that is:

- 1971 L of H2 1bar
- 2.8 L of H2 700 bar

**1Kg NH3 (liq) (1.6 L) = H2 (1.6 L) 1235 bar**, that means, the same volume (1.6 L) implies an H2 compression about 1235 bar!!!!!

# 2.- NH3 Cracking. Basics.

**Basic reaction: 2NH3 + 92KJ/mol ↔ 3H2 + N2**

**NH3 cracking can be implemented by:**

- **Temperature as most relevant parameter** (with support from basic catalysts). Temperatures 500ºC-700ºC
- **Advanced catalysts.** Lower temperatures and higher dissociation ratio (reaction tends to the right, dissociation).

**Dissociation implies a minimum energy 92KJ/mol that represent around 13% in terms of H2 content.** In other words, **maximum energy efficient 87% without losses and 100% cracking reaction**.

**TARGETS:**

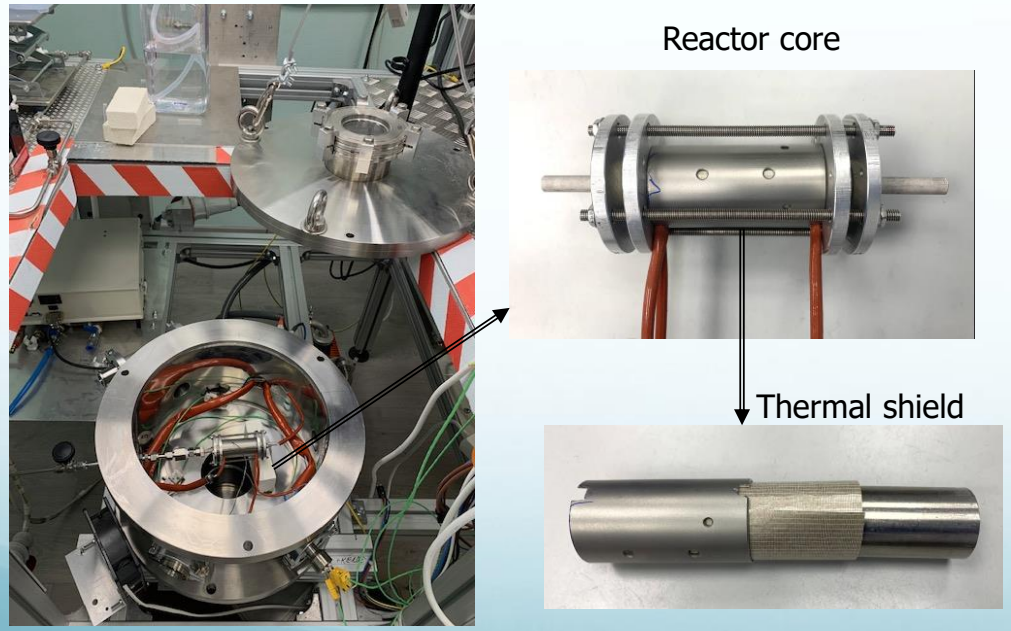
- **30% maximum losses in terms of H2 content, that means 70% output H2.**
- **Lower temperature → lower power consumption**
- **To favor cracking: capture H2 to provoke more NH3 dissociation**

**SOLUTIONS:**

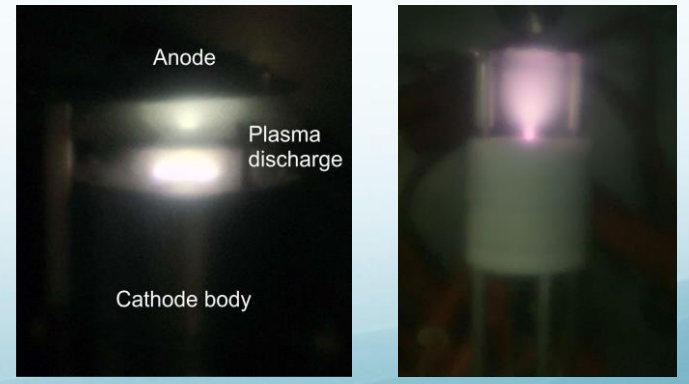
- **New catalysts materials and concepts. Electrodynamics vs. passive (temperature) catalysts (Patented). LOW TEMPERATURE AND HIGH DISSOCIATION RATIO.**
- **Thermal Energy Confinement. (High reflectance patents). LOW THERMAL LOSSES. More than 70% of thermal losses saved.**

# 3.- NH3 Cracking. Solutions.

**SOLUTIONS: New catalysts concepts and very low thermal energy losses.**
**Catalyst** based on N2 and H2 **adsorption, ionization and neutralization**. Materials with controlled bandgap allow **charge separation** (catalysts bed based on high temp semiconductor), complementary adsorption-ionization materials ($N2 \rightarrow 2N^+$, $H2 \rightarrow 2H^-$) in addition with high electrical conductivity allows an easy charge balance and ions neutralization. **Pulsed bias control (Patented). Low temperature operation (200ºC-400ºC).**
**Low thermal losses:** minimum thermal conduction losses and **thermal energy radiated confined** by high reflectance shields and **very low emittance by the hot nucleus (Patented).**




**Background**
First plasma neutralizer for space propulsion NH3 fueled, presented in the International Electric Propulsion Conference (IEPC), jun-2022, MIT, Ma. (USA)

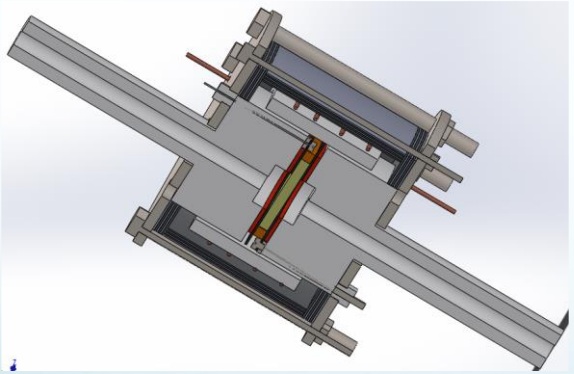


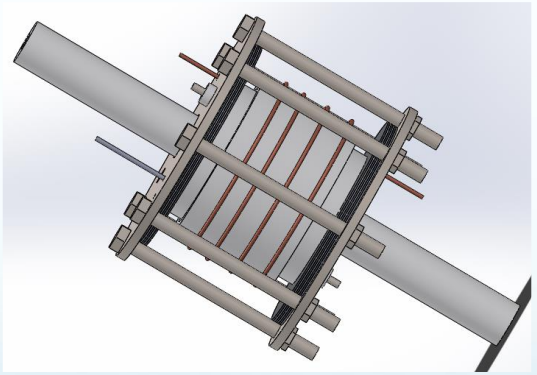
# 3.- NH3 Cracking. Other features.

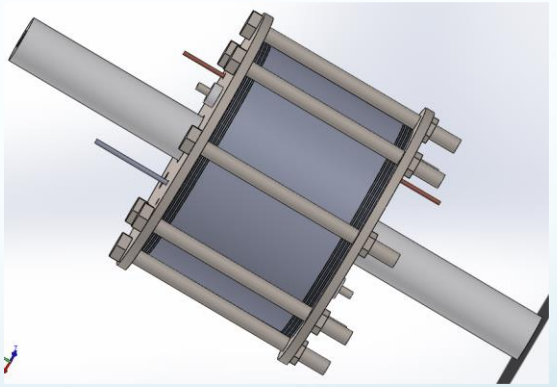
**PURE H2 EXTRACTION AND SOLID STATE PUMPING SYSTEM**

**H2 EXTRACTION** through an **ACTIVE PROTON MEMBRANE (APM),** a ceramic membrane developed by ATD with very high proton conductivity that provides:

- Extracting H2 provokes the reaction shifts to the right, increasing dissociation to replace the "H2 lack".
- H2 purification at the higher levels: only protons (H+) can pass through the membrane. 99,999% H2 purity.,
- Extra feature: H2 pumping in the output without mechanical pumping/compressors. Up to 350 bar H2 pressure in the output.







**NH3 dissociation at different grades (10%-99.999%), with or without H2 purification and pressurization: OPEN ARCHITECTURE.**

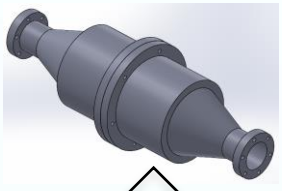
# 3.- NH3 Dissociation. OPEN ARCHITECTURE

**Target: 15% - 30% energy consumption**

**Target: 70% efficiency**

**Low Thermal Losses REACTOR**
- **Ru-"electride" catalyst**
- **Thermal energy confinement**

**NH3**



**rNH3+3H2+N2**

**ACTIVE MEMBRANE SYSTEM**

**Pure H2 (99,999%). Pressurization from 2 to 350 bar "without pumping/compressor" (no noise nor vibrations).**

**Very low energy consumption**

**NH3 CAPTURE**

**H2+N2**
**H2 from 10% to 95%**
**Minimum NH3 traces (10-100 ppm)**

**REACTOR CONTROL**
**Energy vs. NH3 dissociation rate from 10% to 95%**

**No energy consumption**

**DIRECT USE:**
**NH3 FUELED SYSTEMS**
**NH3+N2+nH2**
**H2 from 10% to 30%**

# 4.- NH3 Cracker specs.

| | Energy (KWh) per Kg NH3 cracked | | | | |
|---|---|---|---|---|---|
| | ATD TARGET SPECS | | KWh output / KWh NH3 in input | | |
| | KWh/Kg NH3 | % | 15% cracking | 95% cracking | 99,999% purity |
| Mínimum Reaction Energy (Thermodynamics) | 0,764 | 13,0% | | | |
| Basic Cracking (State of the art) | 1,2 | 20,4% | | | |
| Thermal Losses | 0,2 | 3,4% | | | |
| Total Energy (without H2 extraction and purif) | **1,4** | **23,8%** | | | |
| Total Energy per Kg.NH3 in input (H2 content) | 5,88 | 100,0% | | | |
| Energy available after cracking (KWh/Kg NH3) | 4,48 | 76,2% | | | |
| Process efficiency (best case) | 4,48 | 76,2% | 88,6% | 76,2% | 51,2% |
| Real process efficiency expected | 4,41 | **75%** | **88,8%** | **75,0%** | **50,0%** |
| Real process efficiency worst case | 4,116 | **70%** | **89,5%** | **70,0%** | **45,0%** |

| PLANNED RELEASES | Year-Quarter | Comments |
|---|---|---|
| **15% Cracking. < 10 KW** | 2024-2T | |
| **15% Cracking > 100 KW** | 2024-4T | End HIDRAM Project |
| **95% Cracking < 10 KW** | 2024-3T | |
| **95% Cracking > 100 KW** | 2025-2T | |
| **99,999% purity < 10 KW** | 2024-4T | End HIDRAM Project |
| **99,999% purity > 100 KW** | 2025-4T | |

ATD ESPAÑA
ADVANCED THERMAL DEVICES S.L.

*Thanks a lot for your attention.*