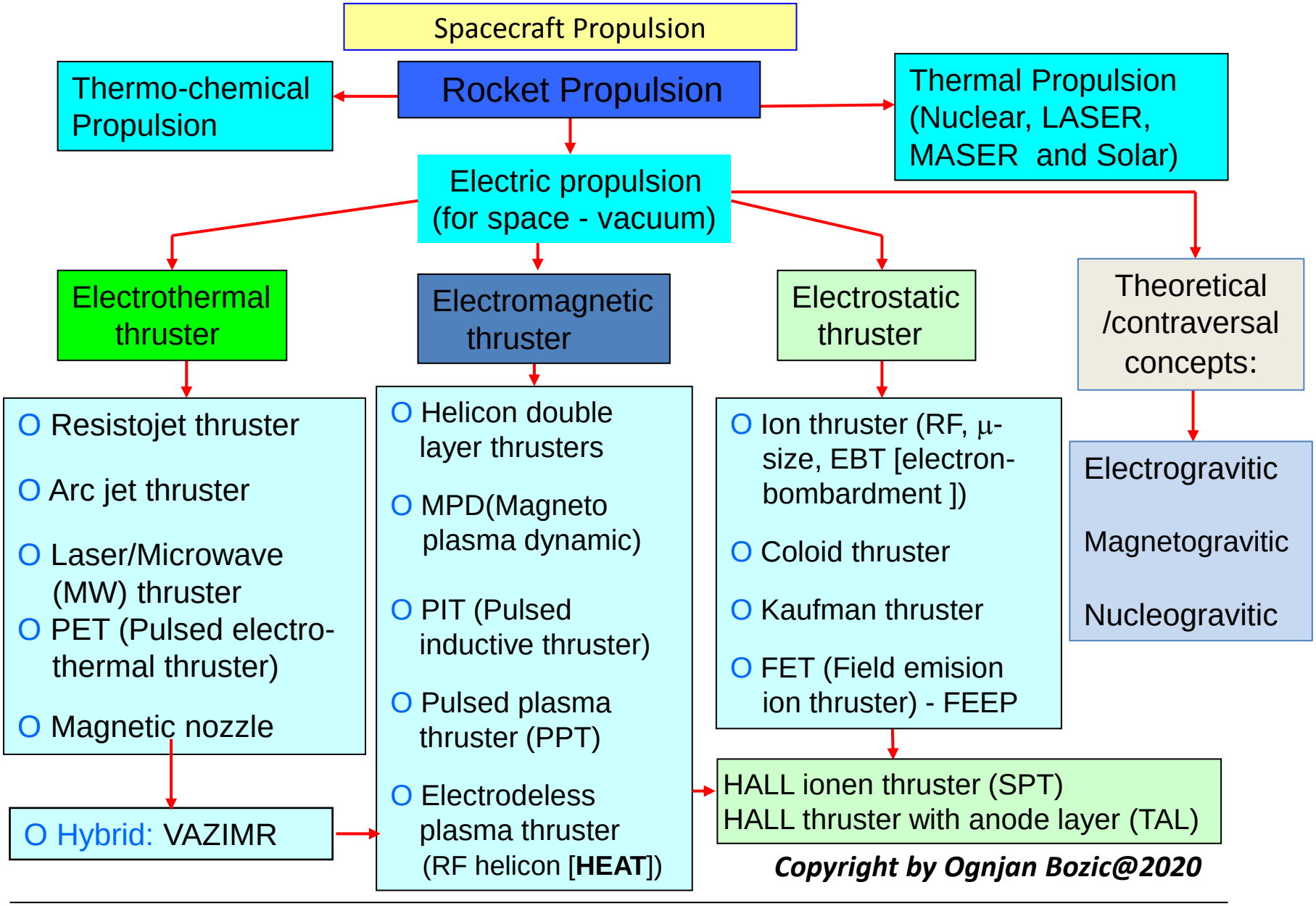
Jadranska
Aero-svemirska
Asocijacija

Adriatic
Aerospace
Association

Electrodeless Electromagnetic Thrusters with High-Density Helicon Radiofrequency Plasma Sources

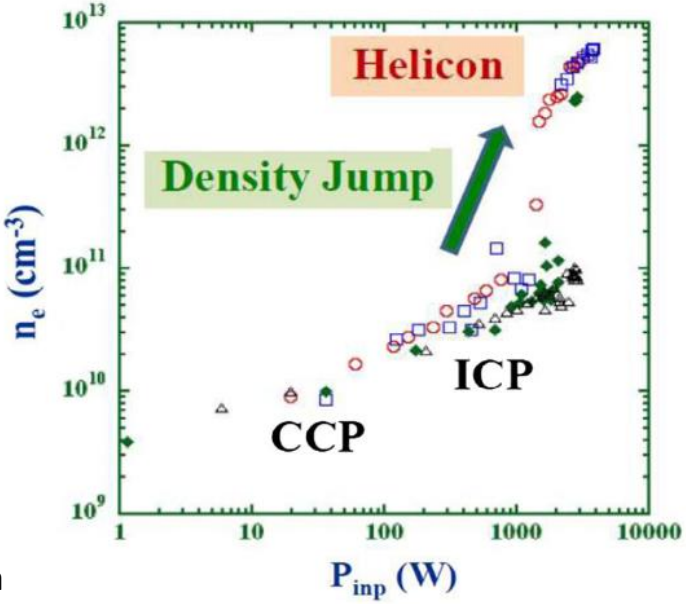
Prof. dr. Ognjan Božić, dipl. ing.

Classification of Electro-Magnetical-Propulsion Concepts



2. Physical nature of the helicon (H-mode) waves

The key of RF plasma source is the RF driven helix like antena, which has the potential to enegize the flow of initial neutral gas into magnetized plazma with high ionization density. The absorption of RF energy is more than 1000 time faster than the theoretical rate due to collision. Helicon wave that propargates through plasma, deposit energy into the plasma.



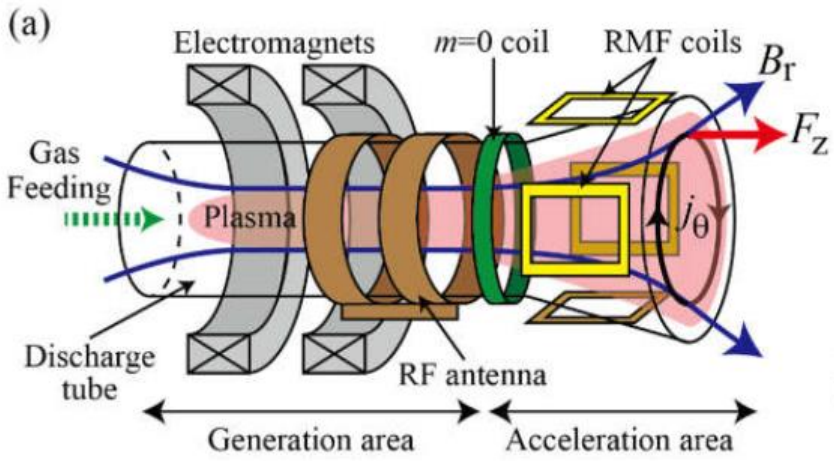
ICP – Inductively Coupled Plasma
CCP – Capacitively Coupled Plasma

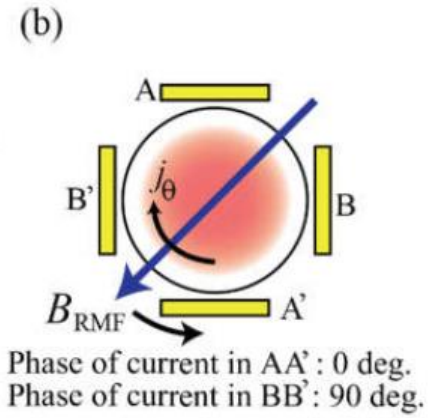
- Helicon waves are **bounded whistler waves** with frequencies between the lower hybrid and the ion plasma frequencies.
- Helicon are usually **coupled with Trievelpiece-Gould (TG)** modes which may account for the efficient power transfer to the plasma in helicon dischages.
- The TG mode had not been identified until recently because of it‘s **fast dampening** causing **all but the plasma edges to behave as thought it did not exist** !
- **Helicon sources can produce dense uniform plasmas efficiently a**nd may find, beside the deep space propulsion, a number of applications in other fields of technology, such as:energy production through nuclear fusion, sterilization of food products, application of gas lasers, coating e.g.

Electrodeless Plasma Thrusters With High – Density Plasma Sources

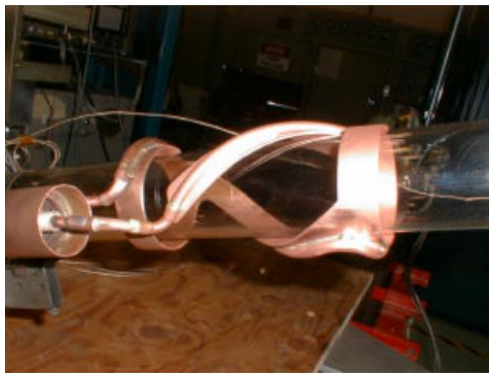
Table 1. Helicon Plasma Thruster prototypes, summary of propulsive performances [4]

Prototype	Power (W)	Thrust	$I_{sp}(s)$	η (%)
HDLT	≈ 1500	6 mN	800	1 ÷ 3
mHTX	700 ÷ 1500	20mN	2000	10 ÷ 20
HPHCOM	50	1.5mN	1200	13
PMEP	700	3mN	500	1
HPHT	2000 ÷ 5000	1-2N	> 2000	55





(c)



Schematic view of high-density plasma Helicon Electrodeless Advanced Thruster (HEAT): (a) side view (b) cross-sectional view of RMF coils (c) helicon antenna with quartz tube through

4.1 Test Plants for Electromagnetic Thrusters

Electric Space Propulsion Test Facility DLR – AS – Department Spacecraft ,Göttingen (STG-ET)

The German Aerospace Center DLR operates micro-propulsion test facilities in Göttingen. Besides the vacuum chambers for chemical and cold gas thrusters DLR extended its activities to electric propulsion and built the facility STG-ET.

Electric space propulsion engines have been used in the past and in current missions (e.g. ESA's Smart1 or NASA's Dawn). These engines are gaining more interest especially in the sector of future missions requesting very low thrust coupled with very accurate thrust level control.

STG-ET is a dedicated electric space propulsion **test facility with a vacuum chamber that measures more than 12m in length and 5m in diameter.** Besides engine tests the focus is on plume interaction with spacecraft components and on long-term testing.

Vacuum chamber of the STG-ET facility (DLR – AS RFZ Göttingen, Germany)

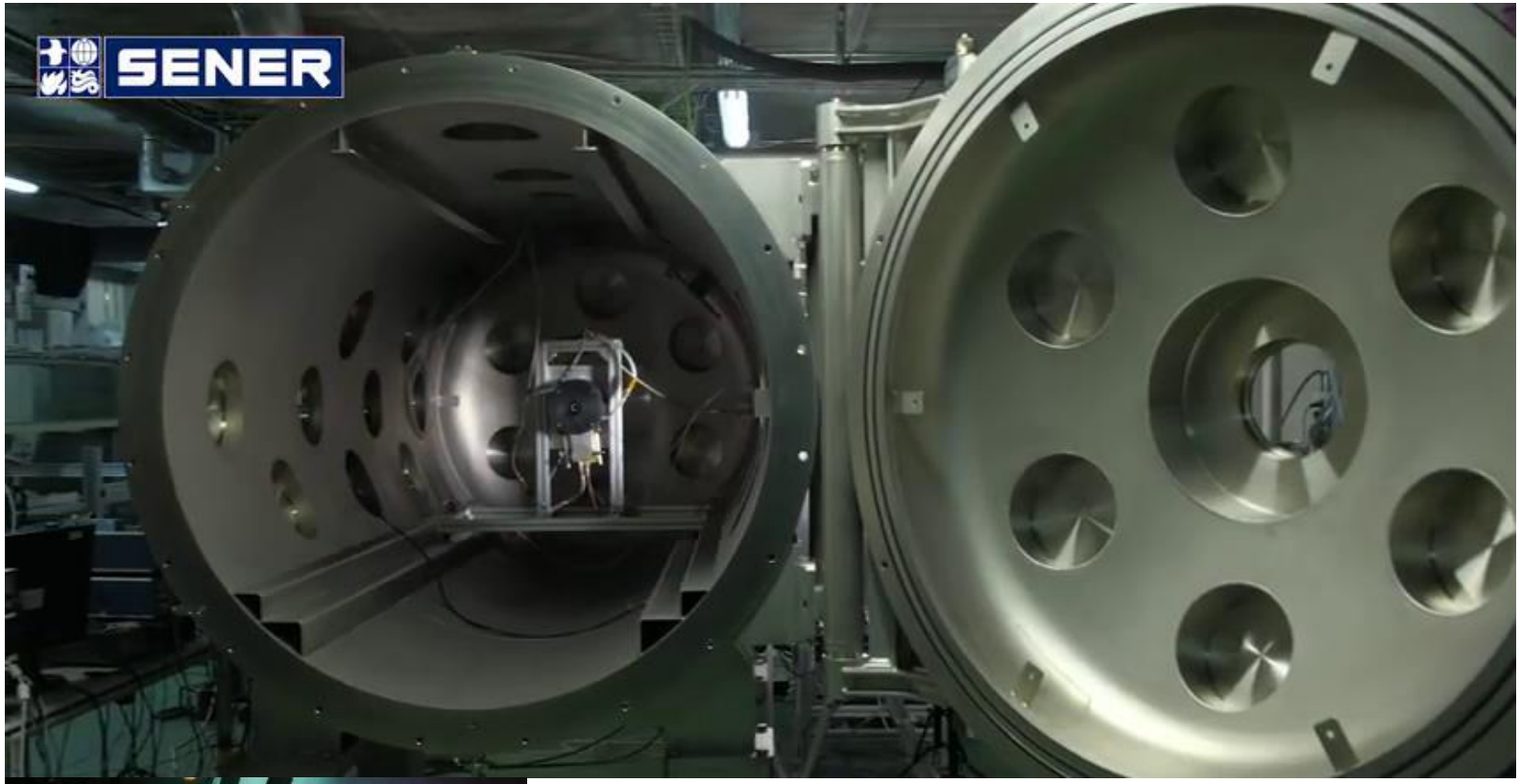
This facility is available for users from research organization's and industry. Features are:

- Electric thrusters of up to 25-50kW (exp. 100 kW)
- Engine lifetime tests and operation with different gases
- Thrust and thrust vector measurement
- Measurement equipment for ion beam profile measurements also in the backflow
- Liquid helium boost pump, up to **400,000 l/s**, non-intermittent operation for about 24 hours per week
- Horizontal axis chamber with 169 mounting ports
- Operation customer oriented, stable/reference conditions

4.1 Test Plants for Electromagnetic Thrusters

Electric Space Propulsion Test Facility DLR – AS – Department Spacecraft ,Göttingen

4.2 Test Plants for Electromagnetic Thrusters

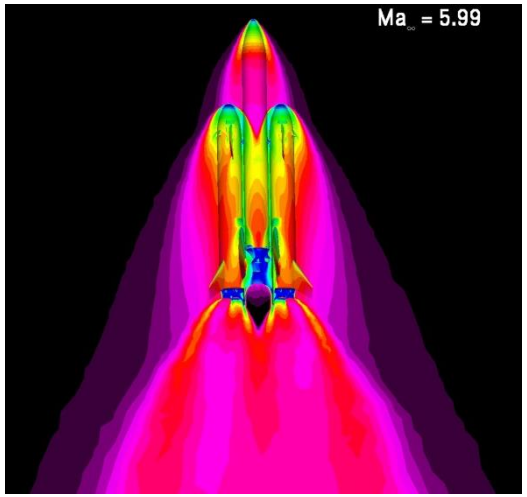


EP2-UC3M in-Space electric propulsion laboratory in Leganés, Carlos III University of Madrid, Spain

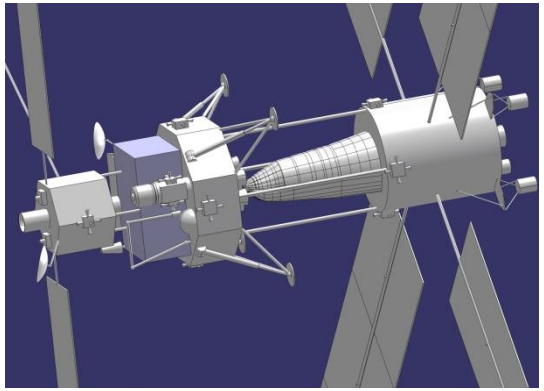
Hon. Prof. Dr.-Ing. Ognjan Božić doktorirao je na Tehničkom sveučilištu u Braunschweigu 2002. godine s disertacijom vezanom za CFD modeliranje heterogenih višefaznih procesa sagorijevanja u generatorima vodene pare.

Božić je 20 godina bio istraživač u German Aerospace Center (DLR) – Institutu za aerodinamiku i tehnologiju protočnih procesa , Braunschweig, Njemačka (do mirovine u prosincu 2018.). Njegov rad je bio usredotočen na kemijski raketni pogon, aero-termodinamiku svemirskih vozila pri povratku u atmosferu Zemlje iz svemira, mehaniku leta raketnih letjelica, sustavnu analizu sustava za lansiranje u svemir kao i razvoj elektromagnetskih ubrzivača (MHD i RAILGUN). Božić je započeo nastavnu djelatnost kao asistent i docent u oblasti obrambenih tehnologija na strojarskom Fakultetu Sveučilišta u Sarajevu MFS), Republika B&H i nastavio karijeru na Tehničkom sveučilištu Braunschweig, Njemačka (od 2010. godine). Trenutno je počasni profesor podučavanja svemirske propulzije na TU-BS na magistarskim studijima. Također je bio uključen u mnoge eksperimentalne projekte kao što su X-38 Crew Rescue Vehicle (NASA), ESA Expert kapsula i SHEFEX 1 suborbitalna kapsula, kao i nekoliko studija izvedivosti kao što je „Misija za povratak uzorka sa mjeseca“ (voditelj studije), MHD propulzija i Buster na tekući pogon sa mogučnosću mekog povratka na Zemlju (LFBB) za raketu-nosač Ariana 5. Njegov rad na dizajnu sustava na podiznom stupnju (buster) rakete „Ariana 6“ i „Vega“ gornji stupanj je najvišeg profesionalnog kvaliteta. Član je Britanskog međuplanetnog društva (BIS, GB), Deutsche Gesellschaft für Luft und Raumfahrt (supervizor odbora za čvrste i hibridne propulzije DGLR-Njemačke), Adriatic Aerospace Association (Hrvatska) te *punopravni* član Međunarodne akademije za astronautiku (IAA). Prof. Božić je također autor preko 70 knjiga i znanstvenih radova objavljenih na međunarodnim konferencijama, kongresima i u referentnim časopisima.

Honorary professor
Dr.-Ing. Ognjan Božić



ARIANE 5/ LFBB launcher -
CFD flight analysis



Earth - Moon - Earth Space Tug
Flight Configuration

ARIANE 6 booster Critical
Analysis / predesign (DLR)