Nammo
SECURING THE FUTURE

FUTURE MISSILE PROPULSION AND SPECIAL AMMUNITION TECHNOLOGY

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NORWAY AND ALLIES LOOKING FOR **EXTENDED RANGE** CAPABILITY

- Protection and surveillance of Northern Sea Territory
- Focus on long range high speed missile capability in the Long Term Plan for the Norwegian Armed Forces
- New International Threat
- Large Interest in Area Protection using existing Platforms

Future Propulsion Goal:

- **Increase Range with Factor > 3**
- **Increase Velocity with Factor > 2-3**

PROPULSION FUNDAMENTALS

1) Specific Impulse: "is a measure of how effectively a rocket uses propellant or a jet engine uses fuel"

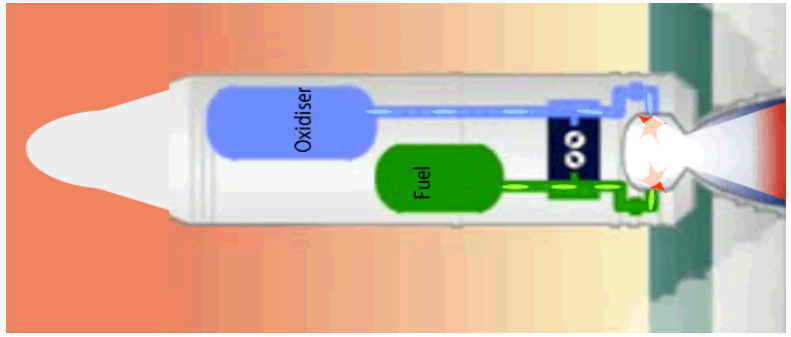
2) Thrust: "proportional with mass flow through the engine"

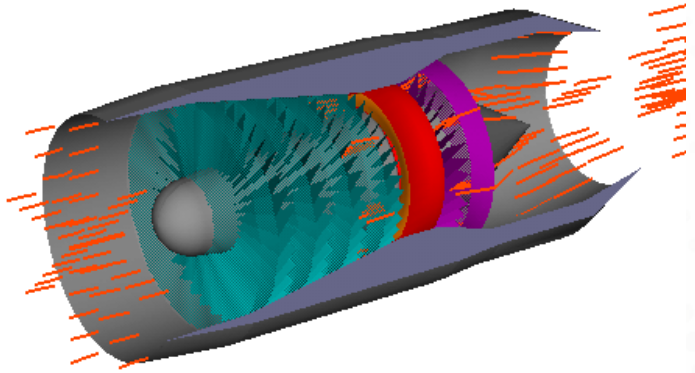
Rocket Motors

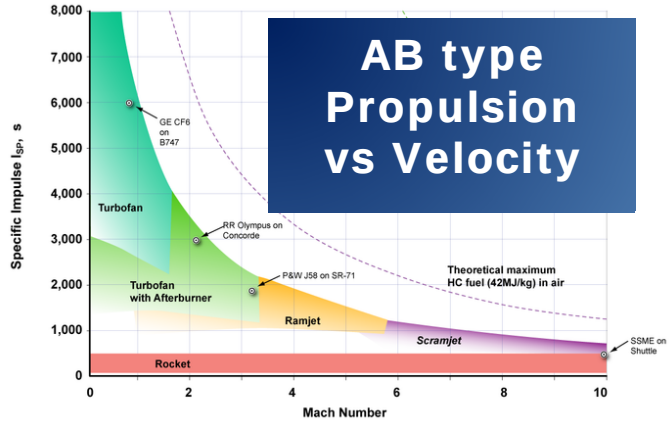
- All fuel and oxidizer (propellant) stored on-board
- Specific Impulse: ~ 2500 Ns/kg

Air-Breathers

- Fuel stored on-board, while air for combustion collected from external
- Mass flow Air: 25-40 * fuel
- Specific Impulse: ~ 15000 Ns/kg





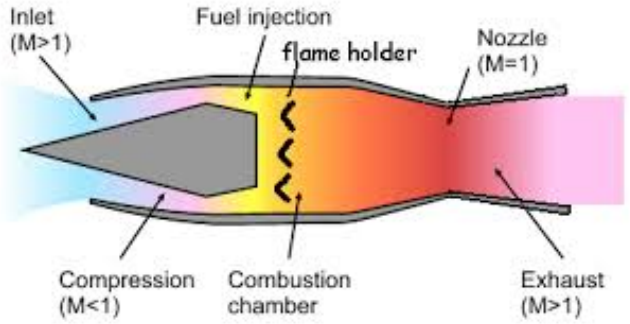


RAMJET SYSTEMS

Liquid Fuel Ramjet

Specific Impulse: 10000-18000 Ns/kg

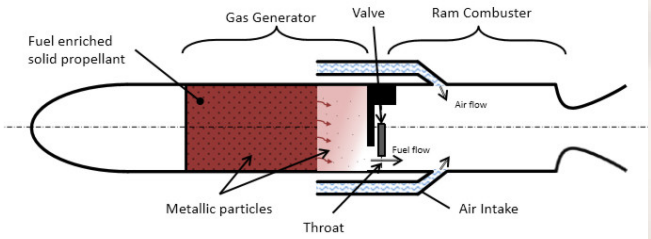
- Most mission flexible
- Largest historic data base
- Very Expensive
- Does not scale well



Ducted Rocket (includes VFDRs)

Specific Impulse: 6000-9000 Ns/kg

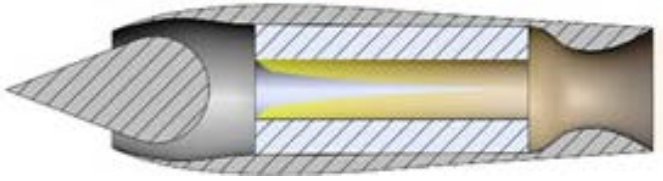
- HSAD, SSST, T3, METEOR
- Lowest performing ramjet type
- Expensive
- Does not scale well



Solid Fuel Ramjet

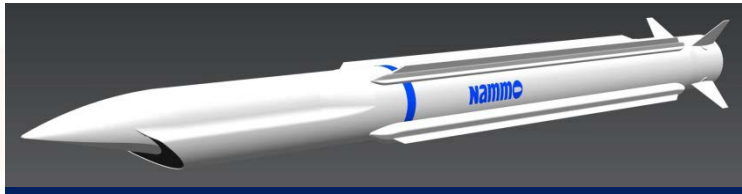
Specific Impulse: 9000-16000 Ns/kg

- Greatest range capability
- Less expensive
- Scales very well



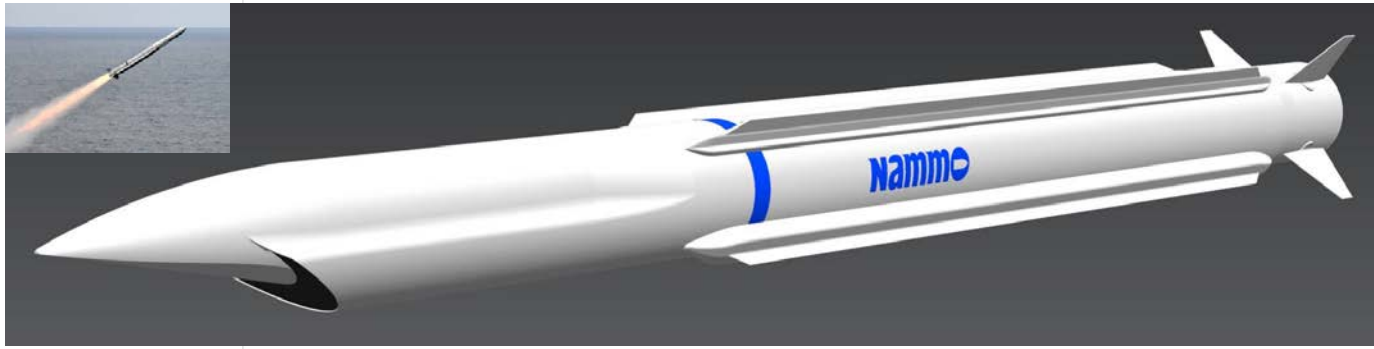
Liquid Engine

Gas Generator (VFDR)



A-SFRJ

RAMJET OPERATION



Launch

1) Air launched
2) Ground or Surface launched

SRM Operation (to Ramjet Takeover)

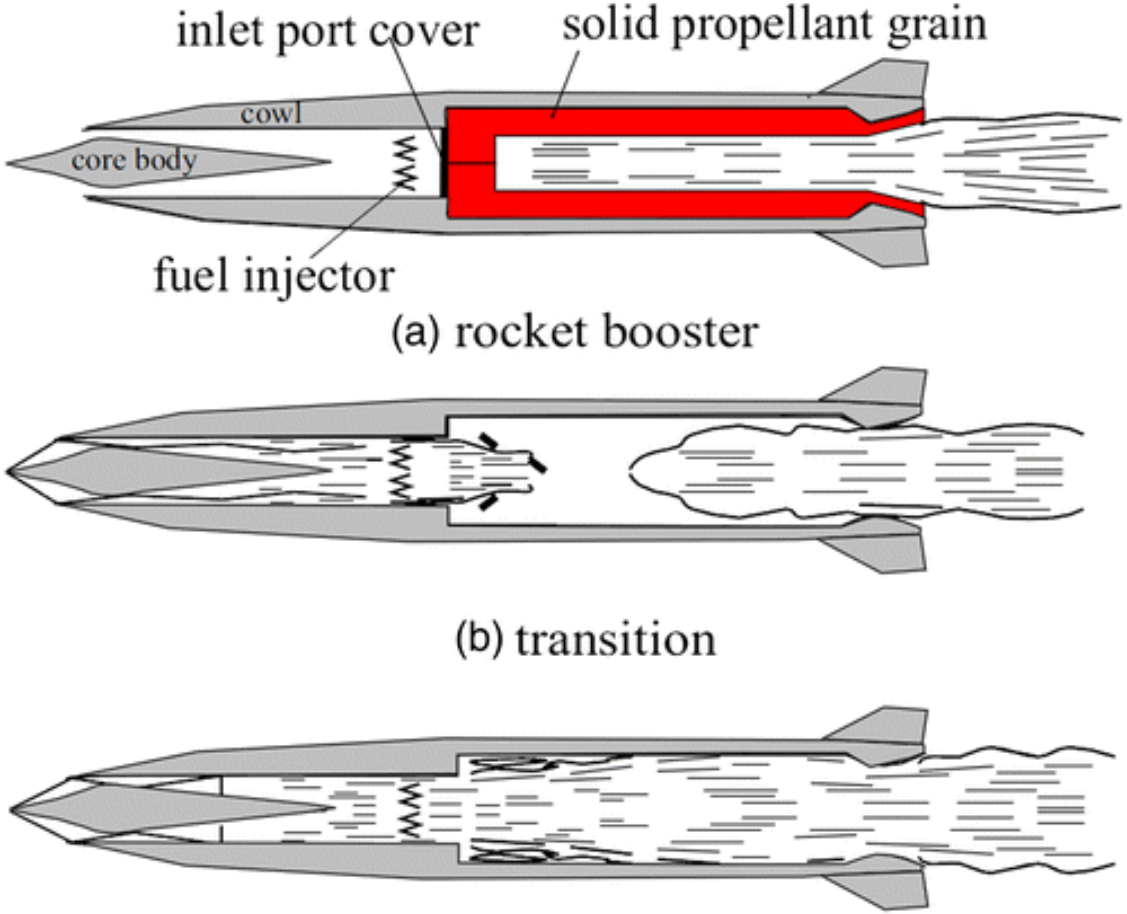
1) Integral booster
2) Ejectable booster

Transition

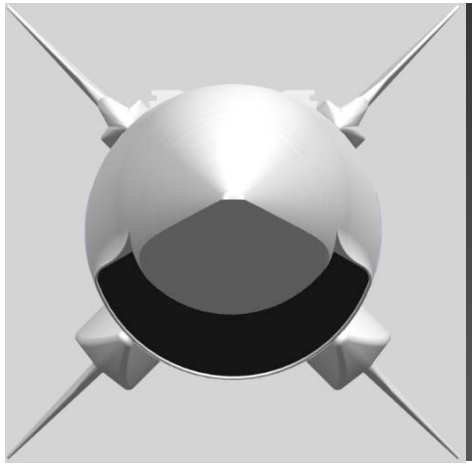
- Combustor cover opening
- Intake cover opening
- Establish flow through RAM combustor

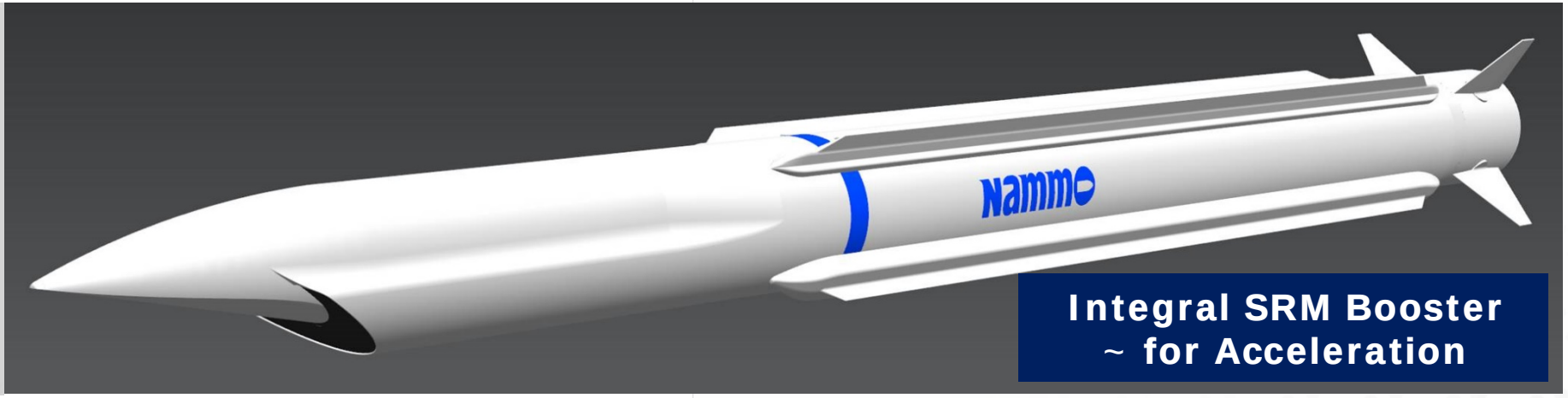
Ram mode

- Ramjet Combustor ignition @ Mach ~2.5
- Ram operation (@ Mach 2-6)



SFRJ OPERATION ON MISSILE





Burn time Booster: 5-10 sec **RamJet Transition: <0.5 sec** **Burn Time RamJet: > 300 sec**

NORWAY **PROTECTED** FROM FRIGATES

Future Long Range ESSM Possibility

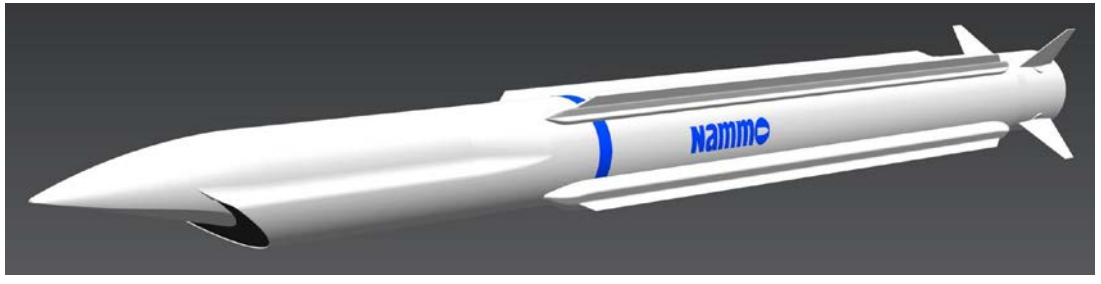
10 in missile configuration

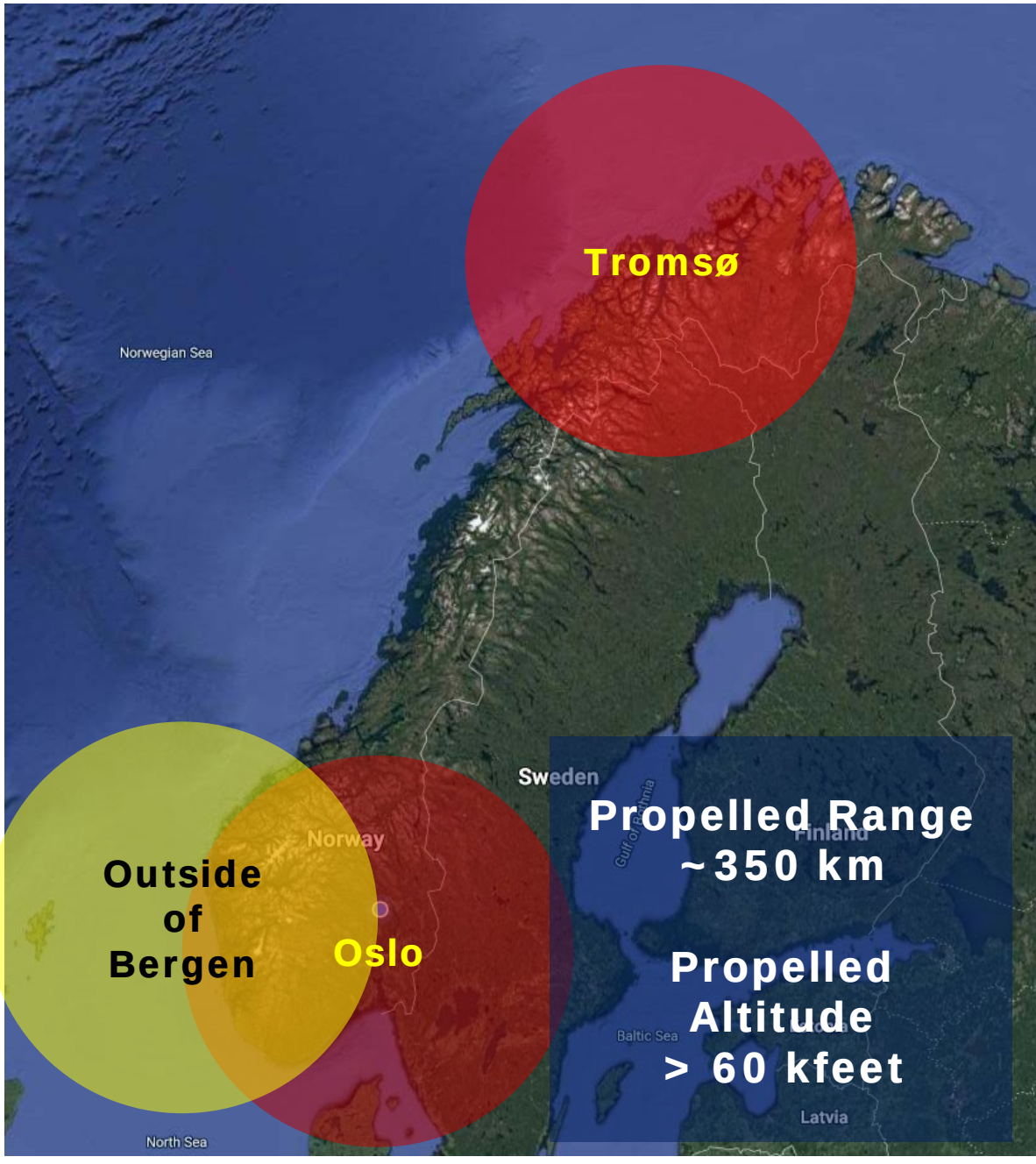
Throttlable Propulsion

Launcher: Mk41, Quad Pack Compatible

Norwegian coast line protected through a few positions

Oil Installations protected from Bergen





COMBUSTOR TESTING

Current Status

- >200 DC tests pr. Nov 2019
- Varying parameters: Nozzle Throat, Fuel Geometry, Injectors, Flame Holders, Mixers , Flow Conditions

Ram transition implemented as start up condition in tests

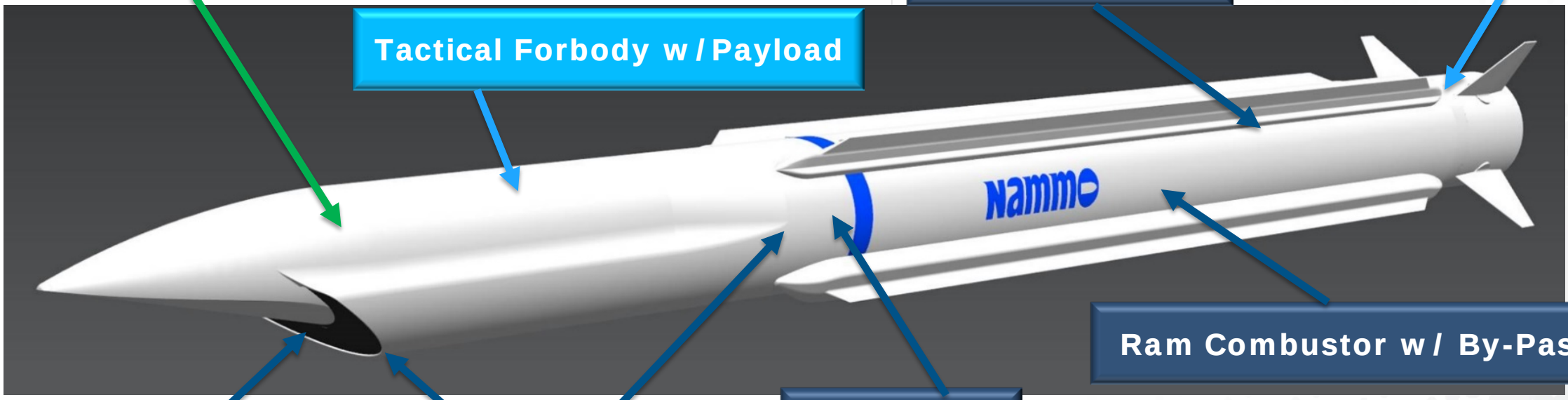
Results:

- Promising combustion efficiency and Ram performance
- Ignition, no pre- heating of combustor

Fuel Consumption:
~8 liter pr 100km at Mach 3.3 and 50.000 feet

RAMJET DEMO FLIGHTS IN NORWAY

- COMPLETE ASSEMBLY IN NORWAY



Flights in Norway:
2021: Ballistic 100 km
2023: CTV 300+ km

SUMMARY

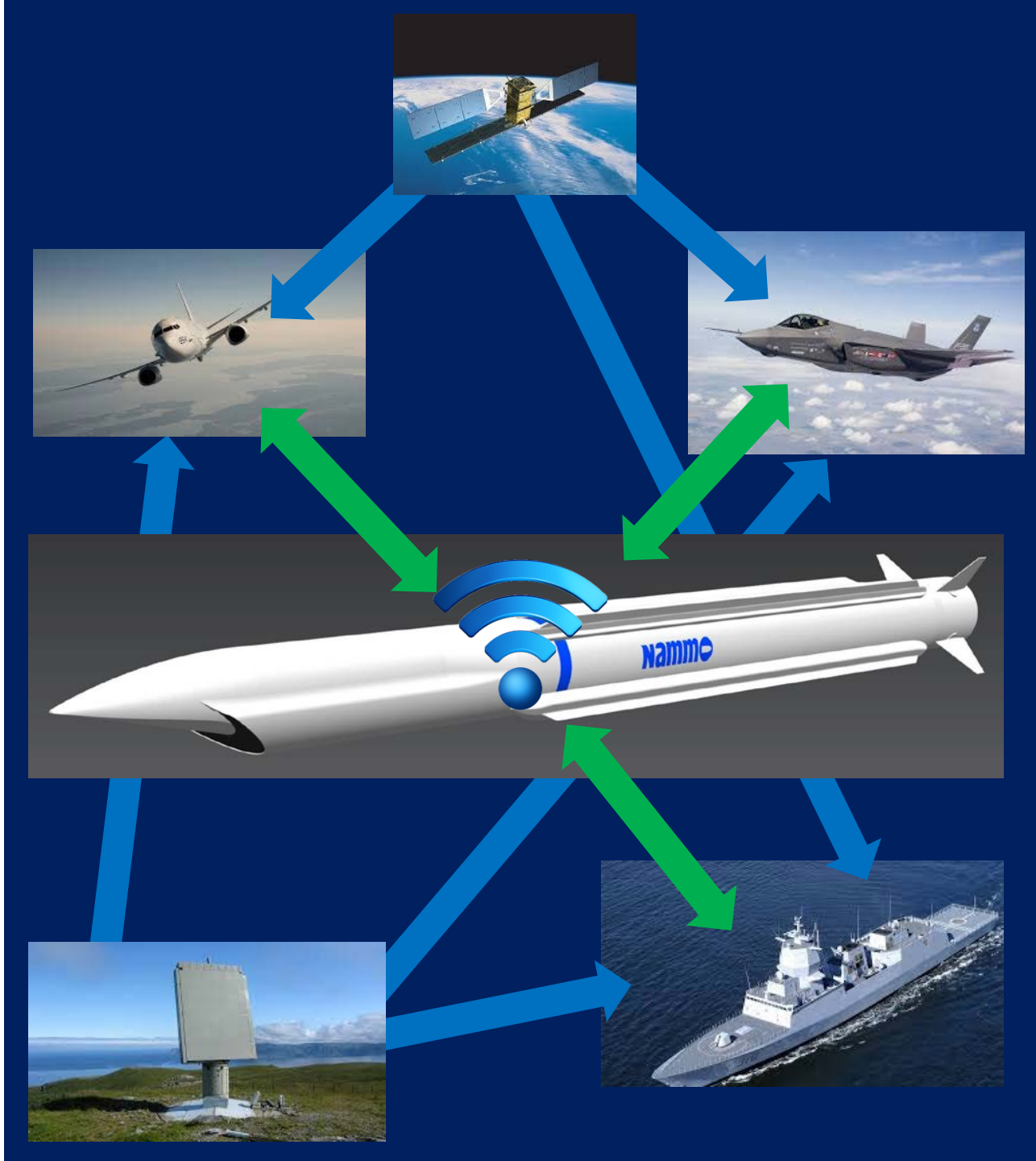
The Solid Fuel RamJet Technology can increase Range with a Factor of 4-5

Time to target is reduced by several factors

Flight velocity: “High Supersonic” (Hypersonic)

Nammo is investing into “a future propulsion system”

Long Range high Speed Flights possible through Existing communication network



HYPERVELOCITY

Hypervelocity

- Normally defined at Mach 5
- Plasma cloud around missile ➔ plasma stealth

3M22 Zircon

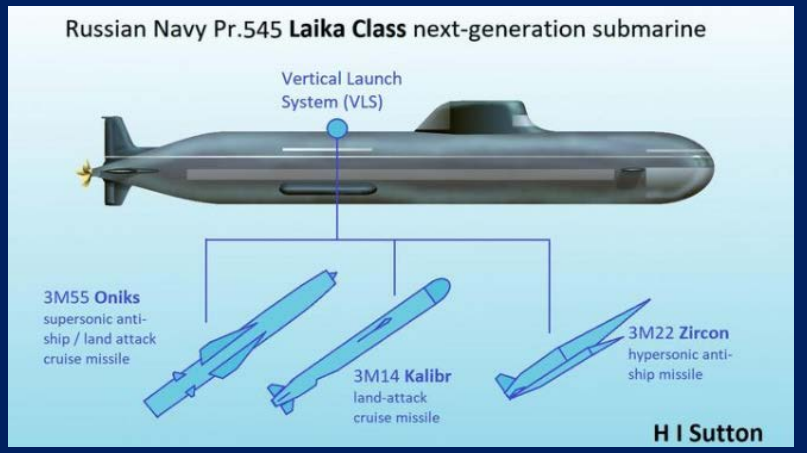
- Mach 8?, Range 400km?

Boeing X-51 (Demonstrator)

- First successful long range flight May 2013
  - Accelerated with SRM booster
  - Mach 5.1 for 210 sec

Technology Challenge

- Skin Temperature ➔ Is Ma 8 Low Altitude Realistic?



Velocity [-]	Ma 1	Ma 2	Ma 3	Ma 4	Ma 5	Ma 6	Ma 7	Ma 8
Skin Temp [degC]	58	230	518	922	1440	2074	2822	3686

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SECURING THE FUTURE

SPECIAL GUN AMMUNITION TECHNOLOGY

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Presentation of MAD-FIRES based upon Open Available Internet Information with the consent of Raytheon which is prime contractor

MULTI-AZIMUTH DEFENSE FAST INTERCEPT ROUND ENGAGEMENT SYSTEM (MAD-FIRES)

DARPA PROGRAM:

1) Raytheon: Guidance Unit & Front End
2) Nammo: Rocket Motor Demonstrator

MAD-FIRES

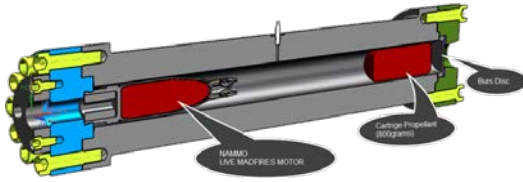
- 57 MM PROJECTILE

Excerpts from DARPA Web Site Program Description:

- “combine the guidance, precision and accuracy generally afforded by missiles with the speed, rapid-fire capability and large ammunition capacity afforded by bullets”

- “aims to incorporate enhanced ammunition rounds able to alter their flight path in real time to stay on target, and a capacity to continuously target, track and engage multiple fast-approaching targets simultaneously and re-engage any targets that survive initial engagement.”

TECHNOLOGY WORK WITH RAYTHEON



- MADFIRE (RMS DARPA PROGRAM)

Light Weight RM, thin Walled pressure balanced Design (World First)

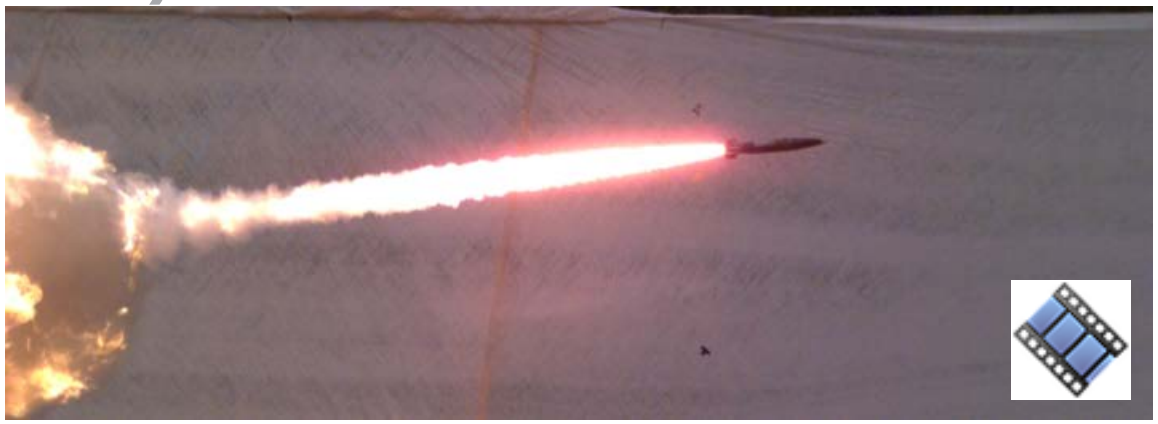
RM Ignited by Gun Gases

Motor Development with tests in Bomb Simulator at Nammo

- External Pressure: 0-2400 bar in 2 msec

RM maintains momentum for several seconds

- High maneuverability
- No loss of speed during engagement



Phase I

6 Soft Launch Flights for Stability & Control

4 Successful Gun Launched Flight Tests (Nov'18 – May'19)

Phase II

– Gun Survivability Test Motors

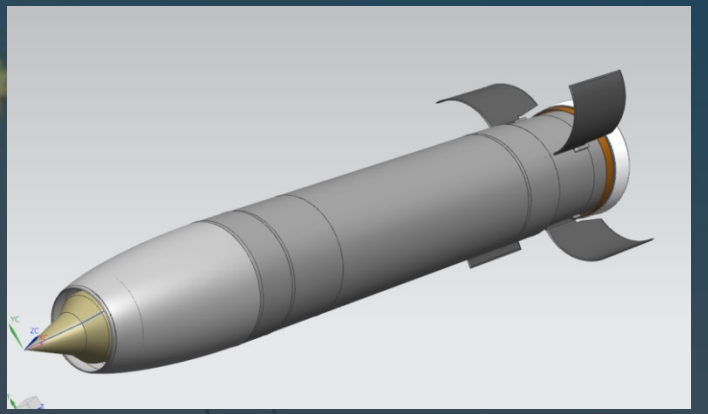
– Guidance and Maneuverability Testing

Testing scheduled Dec'19 (3 successful flights) to Apr'20

155MM RAMJET PROJECTILE DEMONSTRATOR

Boeing and Nammo working with extreme range firepower to US ground forces

Extreme precision and range giving artillery a new dimension



Flight Tests:
2020: Ballistic 100 km
2021: Guided 100+ km