Development of Weather Modification Rockets in Thailand

Pawat Chusilp
Defence Technology Institute (DTI), Thailand

ASEAN Workshop on Weather Modification 2018
6-9 August 2018, Thailand

Outline

- Background
- Project Description
- System Design and Development
- Testing
- Summary and Future Works

Outline

- Background
- Project Description
- System Design and Development
- Testing
- Summary and Future Works

Background

- Application of rockets in cloud seeding in Thailand has been investigated after his Majesty King Bhumibol Adulyadej initiated the first rainmaking experiment in Thailand in 1969.
- During 1970s and 1980s, some important progress were made by a joint effort of several government and military agencies.
- But these research works were stopped or did not continue.

His Majesty King Bhumibol Adulyadej explaining clouding seeding technique

- In 2016, a project to develop a rocket system for weather modification in Thailand has been launched again.

Outline

- Background
- Project Description
- System Design and Development
- Testing
- Summary and Future Works

This Project

Objective	Develop a rocket system for cold cloud seeding to support hail suppression and rainmaking operations in Thailand
Output	A prototype rocket system
Target User	Department of Royal Rainmaking and Agricultural Aviation (DRRAA)
Period	3 years, 2016 - 2018
Participating Agencies	

Participants

Agencies	Tasks
Department of Royal Rainmaking and Agricultural Aviation (DRRAA)	▪ Define user requirements ▪ Provide expertise in cloud seeding technology ▪ Operate weather radars ▪ Support dynamic tests
Defence Technology Institute (DTI)	▪ Design the rocket system ▪ Develop prototype rockets and launchers ▪ Perform system testing
Research and Development Center for Space and Aeronautical Science and Technology, Royal Thai Air Force	▪ Develop pyrotechnic devices and silver iodide flares ▪ Develop telemetry payloads ▪ Support dynamic tests

3-Year Plan

2016	2017	2018
Proof of Concept	Prototype System	Field Tests and Evaluation
• 10 Test Rockets • 1 Test Launcher	• 100 Prototype Rockets • 1 Trailer Launcher • 1 Truck Launcher	• 100 Prototype Rockets
• Static Tests • Subsystem Tests	• Static Tests • Subsystem Tests • Dynamic Tests	• Static Tests • Subsystem Tests • Dynamic Tests • Field Test

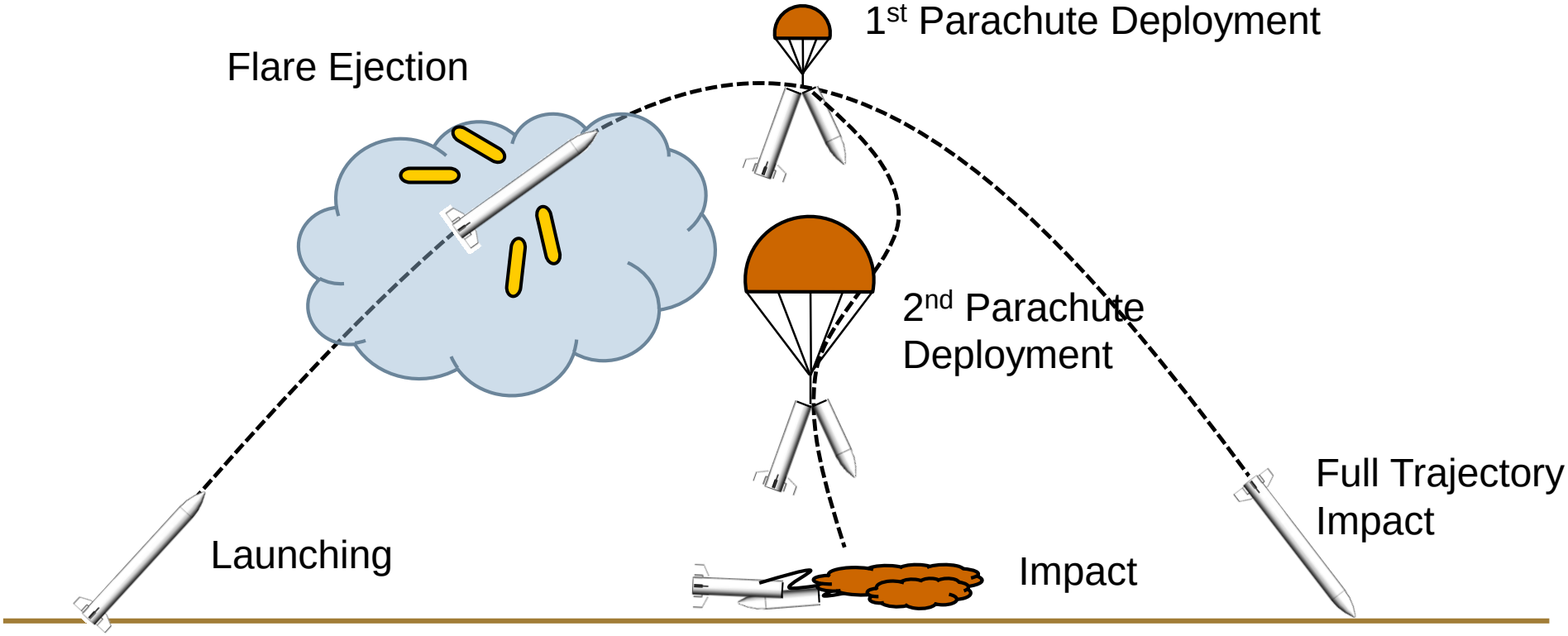
Outline

- Background
- Project Description
- System Design and Development
- Testing
- Summary and Future Works

User Requirements

Item	Description
Target	At the top of cold clouds, approximately 5500 to 7500 m above sea level
Range	Up to 8 km
Accuracy	Circular probable error (CEP) < 150 m
Payload	Silver Iodide flares
Required silver iodide quantity	40 g for each cloud top (1 km radius) for rainmaking 120 g for each cloud top (1 km radius) for hail suppression
Flare burn time	At least 30 s
Launcher mobility	Both stationary and mobile

Concept of Operation

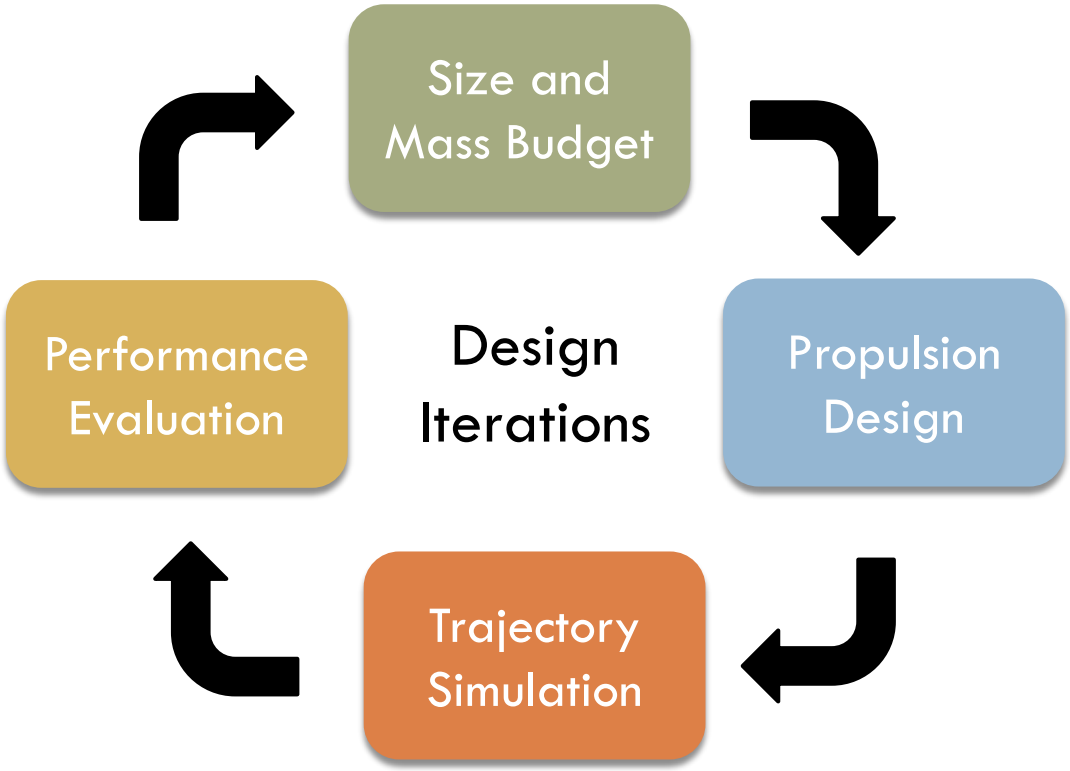


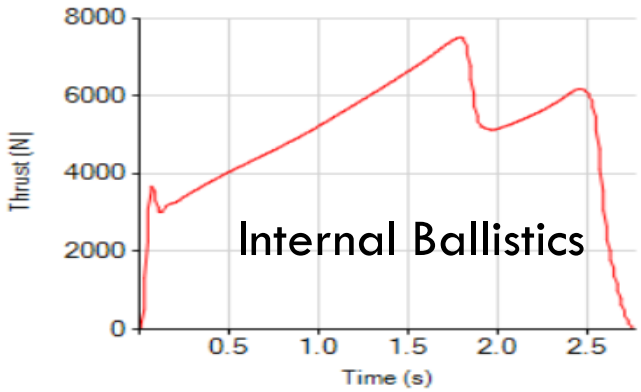
- A rocket that carries silver iodide flares is launched.
- Silver iodide flares are ignited and ejected into the top of cold cloud.
- Parachutes are deployed to allow rocket parts to descent to the ground safely

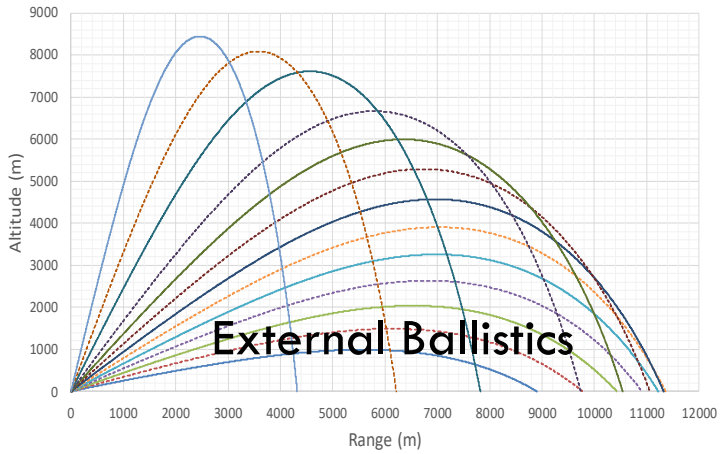
Rocket System

- Weather Modification Rocket System
  - Rocket
    - Rocket Motor
    - Front Section
    - Tail Section
  - Payload
    - Delay and Ejection System
    - Agl Flares
    - Parachute System
  - Launcher
    - Launch Pod
    - Aiming Mechanism
    - Platform
  - Fire Control Computer

Rocket Design and Sizing

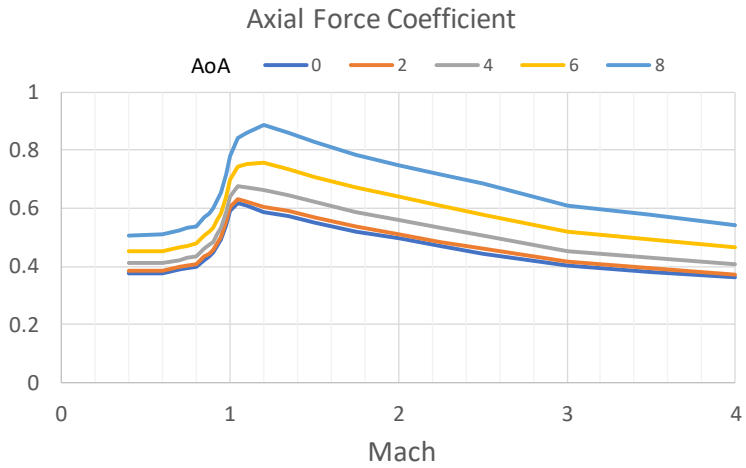






Aerodynamic Characteristics

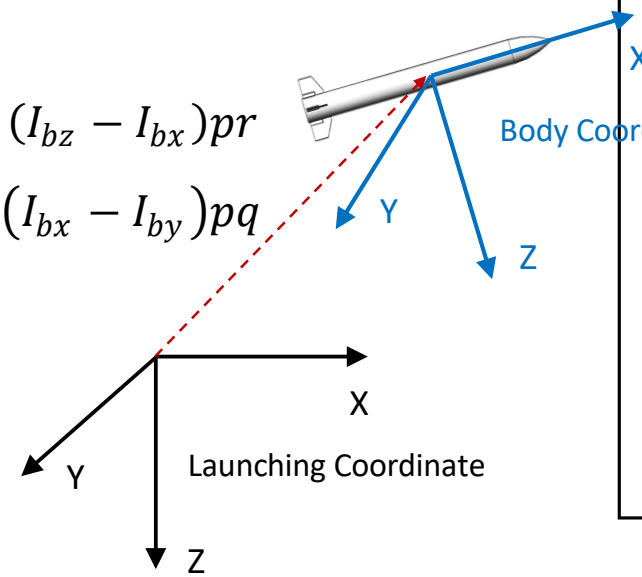
- Aerodynamically stable (static margin 2-5 caliber)
- Body-tail configuration
- 4 trapezoid fixed tail fins
- Prediction tools
  - PRODAS, Missile DATCOM
  - ANSYS Fluent

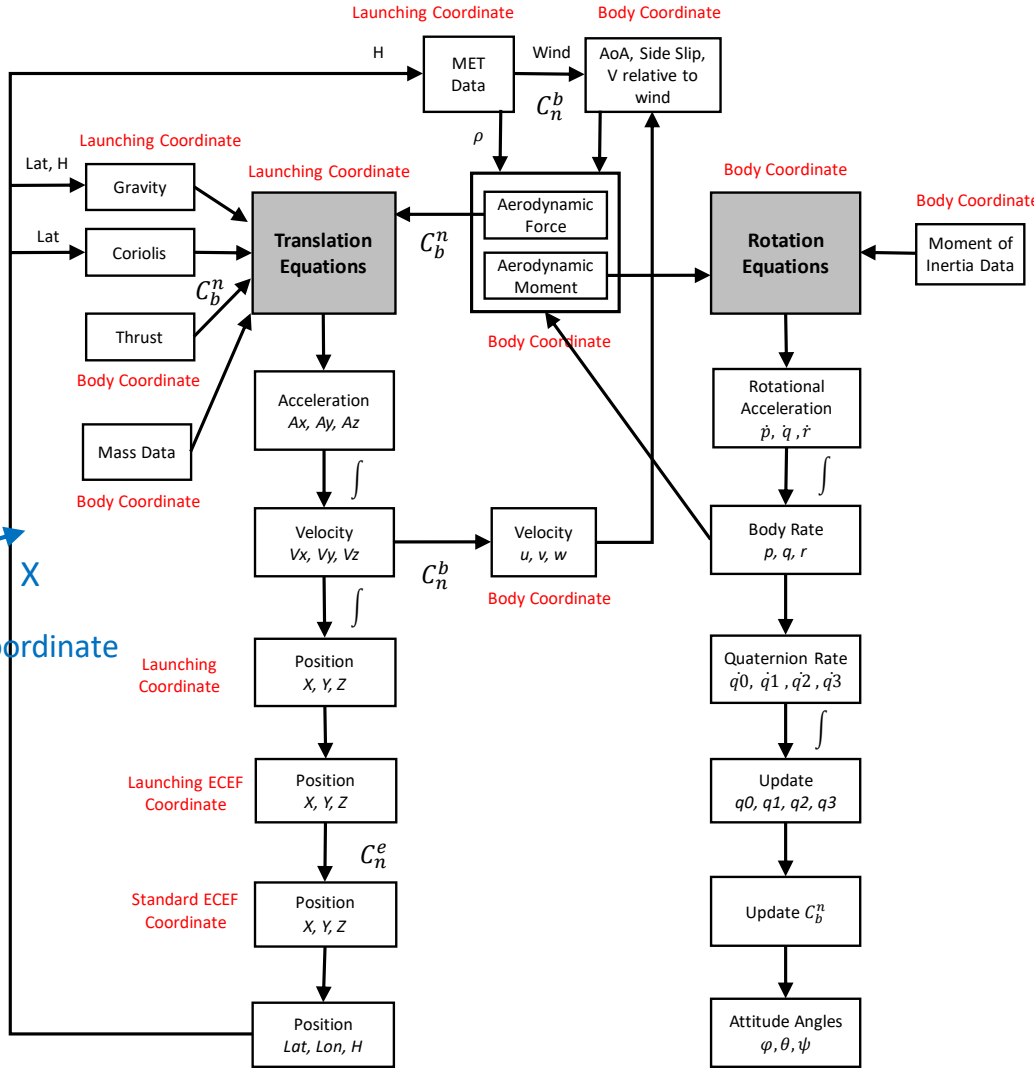


Trajectory Model

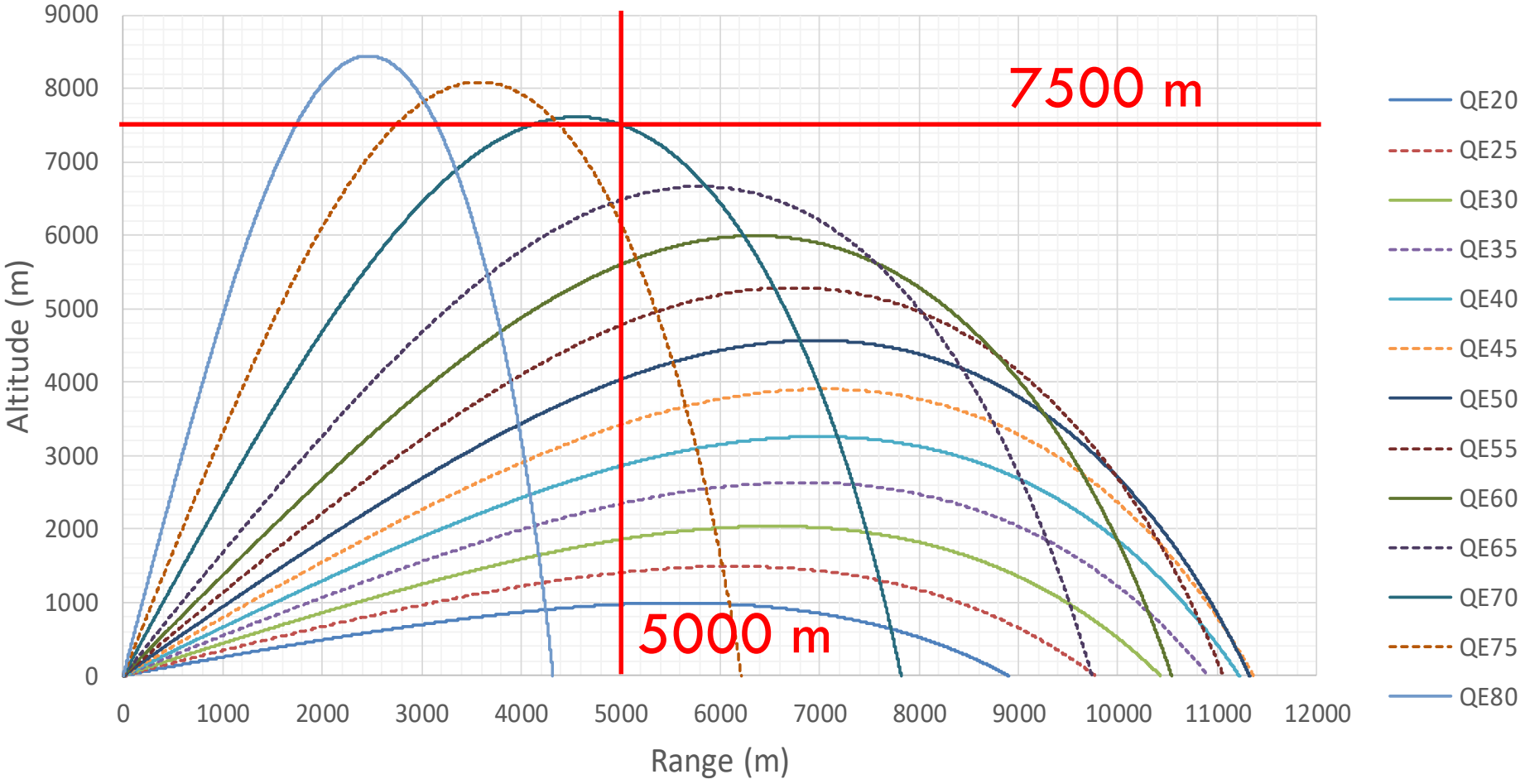
- 6-DOF rigid body motion
- Fourth-order Runge-Kutta integration, Δt 0.01 s

$$a_x = \frac{(P+F_x)}{m} + g_x + ac_x$$
$$a_y = \frac{F_y}{m} + g_y + ac_y$$
$$a_z = \frac{F_z}{m} + g_z + ac_z$$
$$\dot{p} = \frac{M_{bx}}{I_{bx}}$$
$$\dot{q} = \frac{M_{by}}{I_{by}} + (I_{bz} - I_{bx})pr$$
$$\dot{r} = \frac{M_{bz}}{I_{bz}} + (I_{bx} - I_{by})pq$$

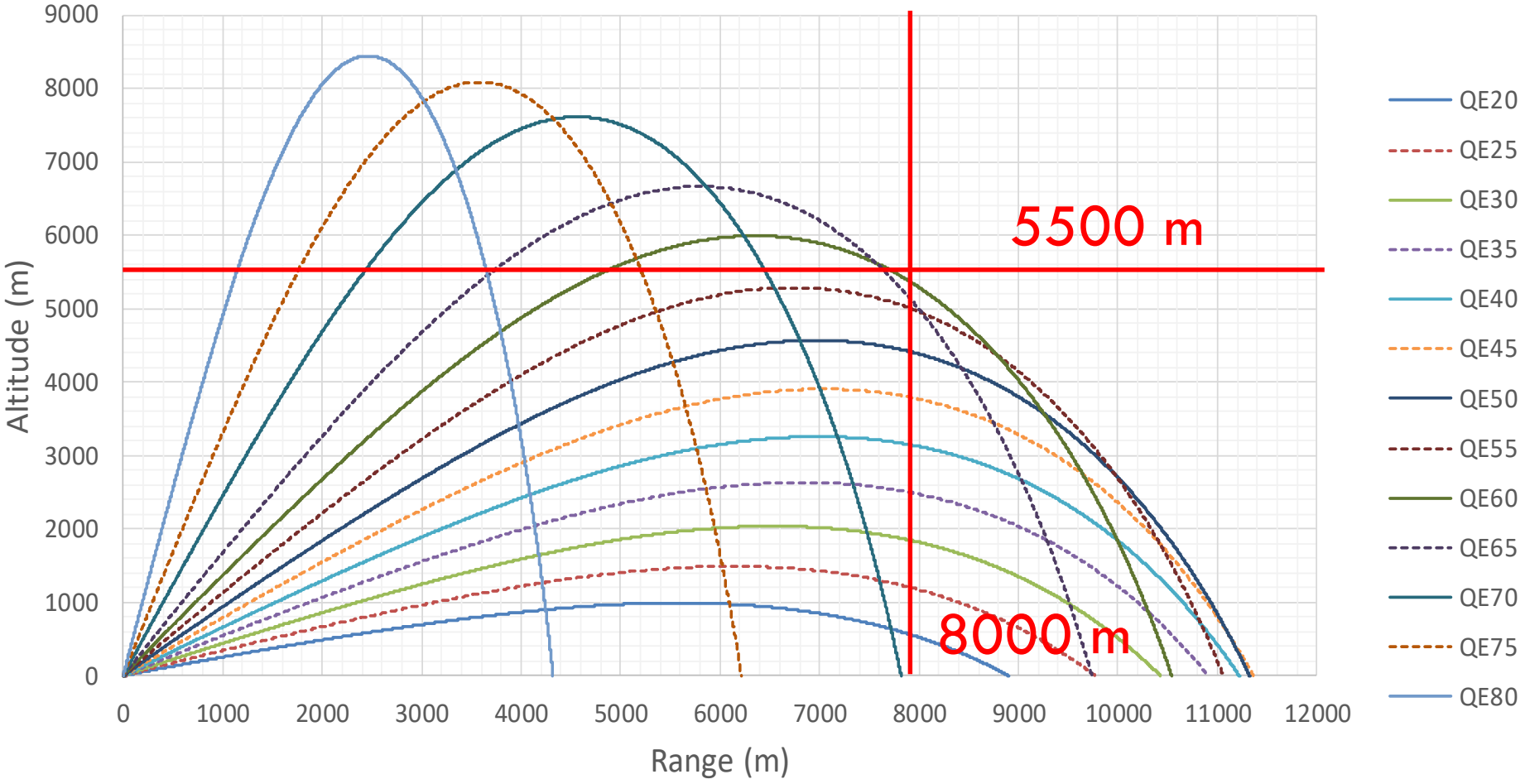




Trajectory

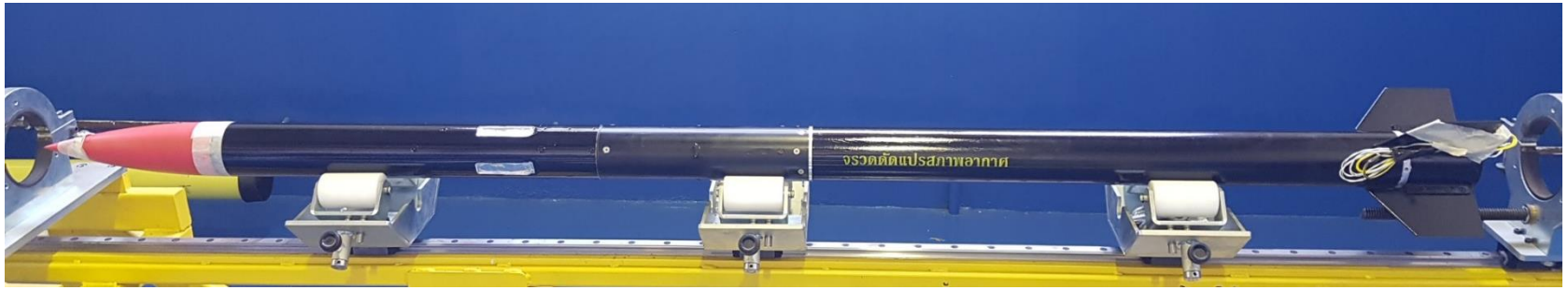

9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Altitude (m)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
Range (m)
7500 m
5000 m
QE20
QE25
QE30
QE35
QE40
QE45
QE50
QE55
QE60
QE65
QE70
QE75
QE80

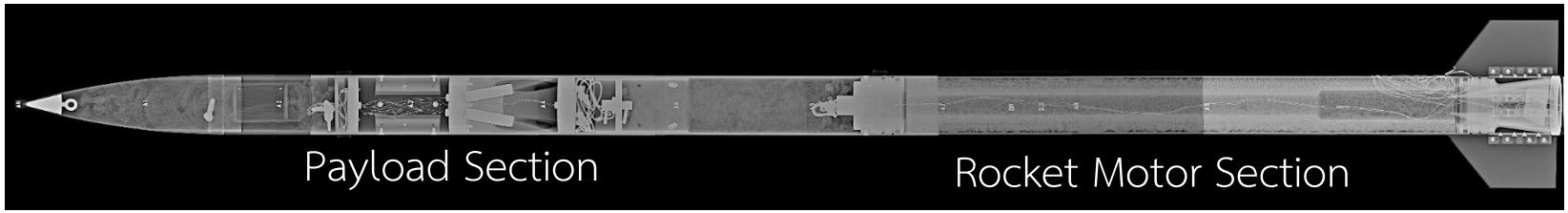
Trajectory


9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Altitude (m)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
Range (m)
5500 m
8000 m
QE20
QE25
QE30
QE35
QE40
QE45
QE50
QE55
QE60
QE65
QE70
QE75
QE80

Body Layout

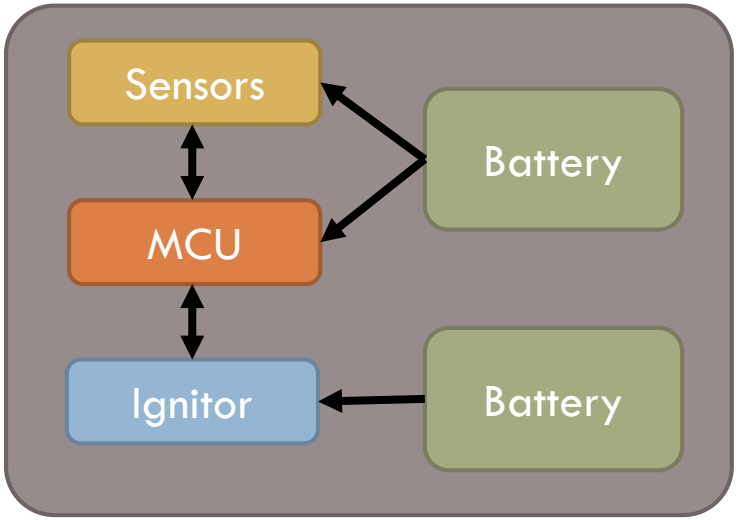

WEATHER MODIFICATION ROCKET


จรวดดัดแปรสภาพอากาศ

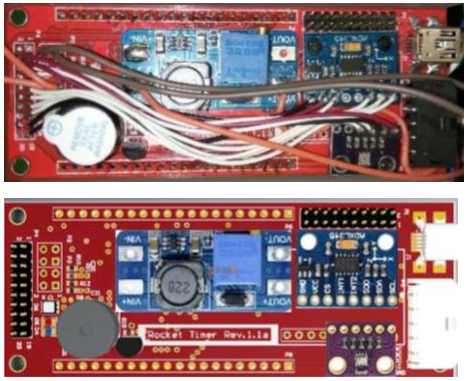

Payload Section
Rocket Motor Section

Delay and Timer System

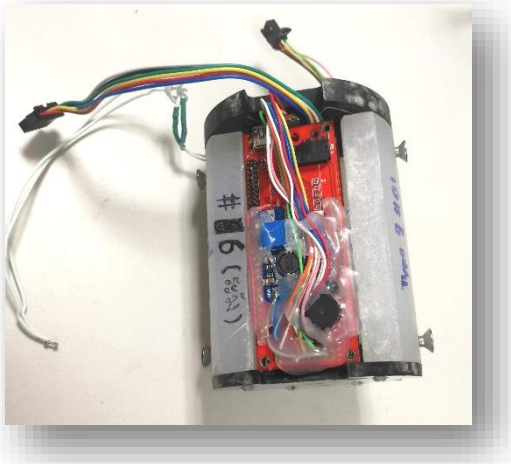
Design



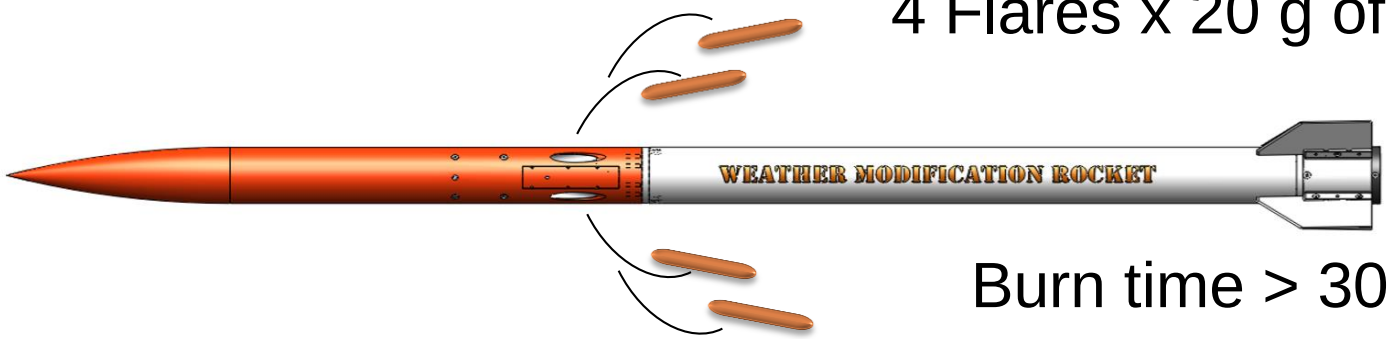
Fabrication



Packaging

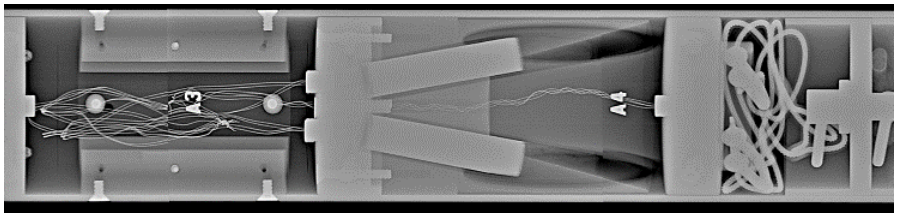


Payload – Silver Iodide Flares



4 Flares x 20 g of AgI

Burn time > 30 s



Parachutes

Parachute 1 for Nose Cone

Parachute 2 (Drogue Parachute)

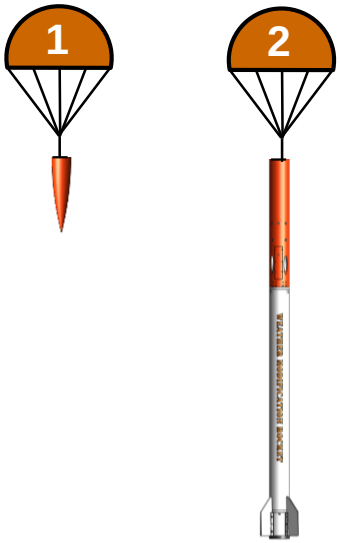
Main Parachute

Parachute Deployment Sequence

Before

V > 130 m/s

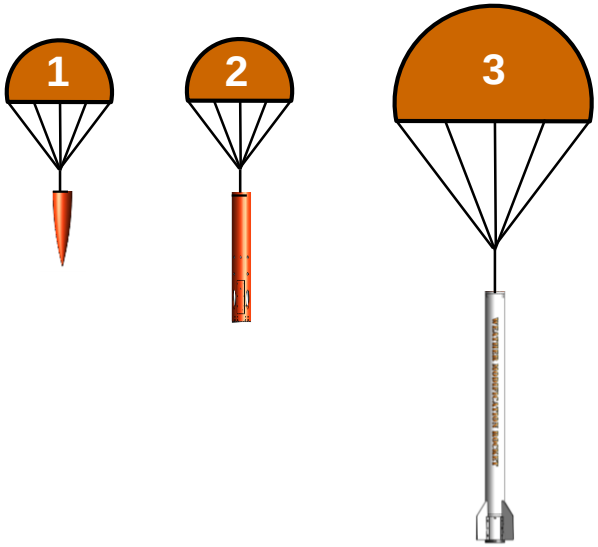
After 1st deployment



Drogue Parachute

Descent rate < 20 m/s

After 2nd deployment



Main Parachute

Descent rate < 6 m/s

Rocket Specifications

Aerodynamic Configuration	Body - Tail
Body diameter	89 mm
Total length	2.3 m
Total initial mass	17 kg
Propellant	6 kg AP composite solid propellant
Burn time of rocket motor	2.7 s @ 30ºC
Total impulse	13 kN.s
Max speed	2.4 Mach
Max g	Less than 50
Max target distance	5.0 km for target altitude 7500 m
Accuracy	CEP < 1.5% of range

Launcher Platforms

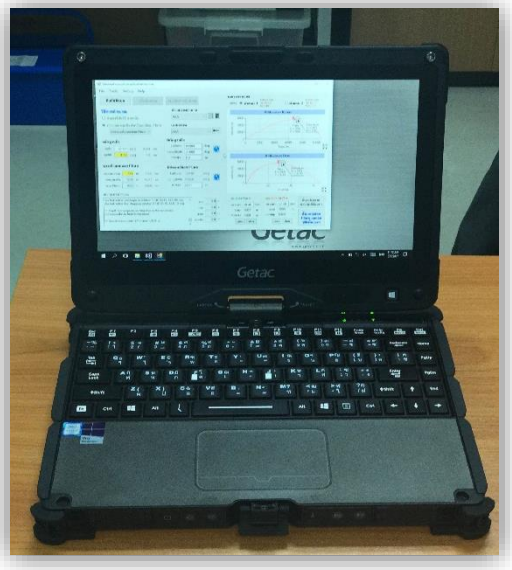
Trailer Platform

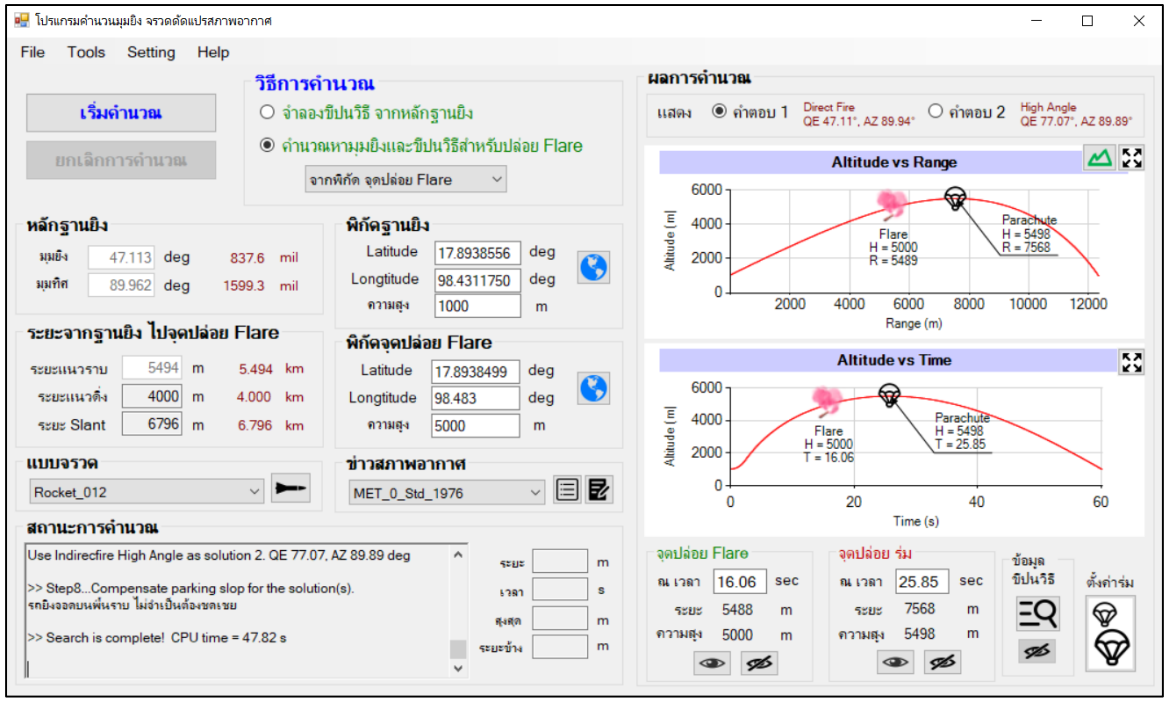
- Lower cost
- Less maintenance

Truck Platform

- Higher mobility

Fire Control Computer





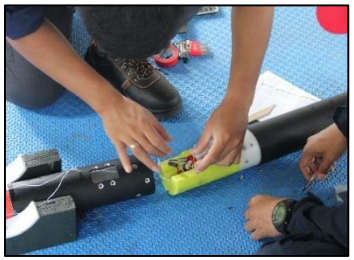
Fire Box

Operation Sequence

Planning and declare NOTAM before the operations

- Identify target clouds
- Calculate firing angles and data — 2 minute
- Program onboard timer — 3 minutes
- Load rocket to launcher — 6 minutes
- Aiming and safety check — 3 minutes
- Fire rocket(s) — 1 minute

Estimated time to launch ≈ 15 minutes


Outline

- Background
- Project Description
- System Design and Development
- Testing
- Summary and Future Works

Subsystem Tests

- Propulsion
  - 2 Ballistic evaluation motor (BEM) test
  - 3 Rocket motor static test
- Flare and Parachute Ejection

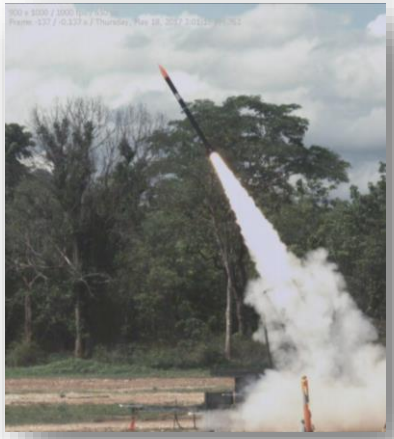
Subsystem Tests

Subsystem Tests

- Qualification Test
  - Reliability Test
  - Aging Test
  - Drop Test
  - Vibration Test
  - Environmental Test
  - Sequential Test

Dynamic Tests

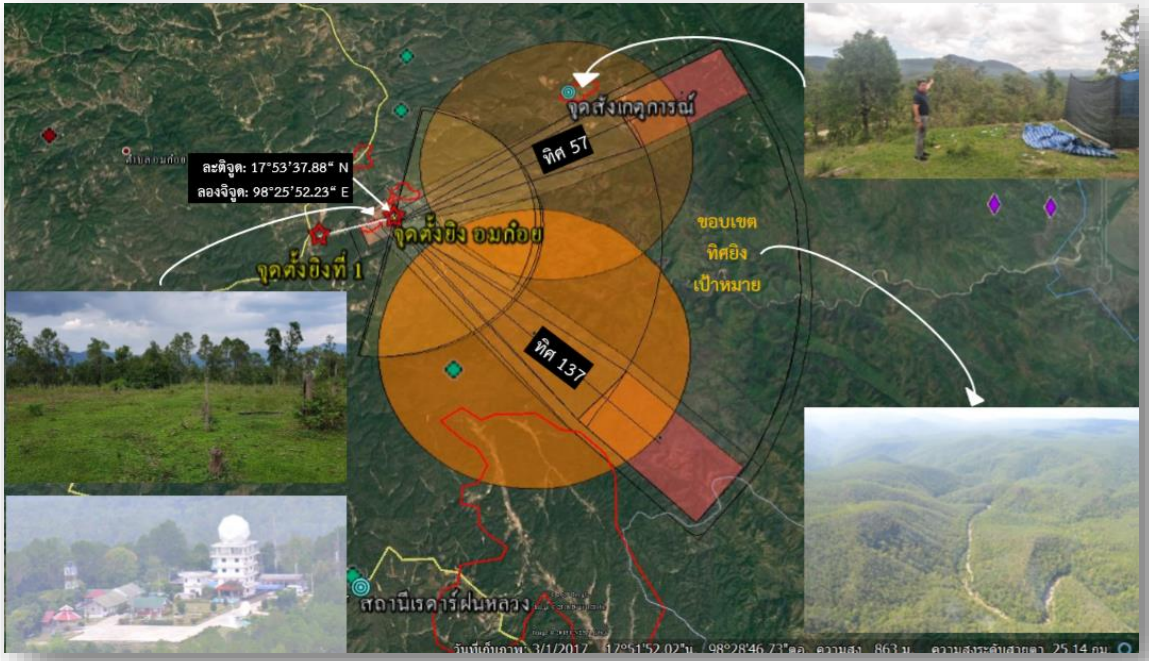
- 10 Dynamic tests to verify
  - Propulsion
  - Delay and timer system
  - Payload and parachute ejection
  - Launcher
  - Trajectory



Dynamic Tests

Field Tests

- First field tests at Om Koi district, Chiang Mai
- Still cannot confirm its effectiveness



Outline

- Background
- Project Description
- System Design and Development
- Testing
- Summary and Future Works

Current Status

- A prototype system was developed.
  - Rocket and payload
  - Launcher
  - Fire control software
- Subsystems were tested and verified.
- 10 dynamic tests were carried out.
- 1 field test was done but its effectiveness could not be confirmed.

Future Works

- More dynamic tests to verity parachute system.
- More field tests to confirm effectiveness.
- Develop the production version.
  - Lower cost
  - More reliable
  - Easier to operate