NERO 1999/2 mei

BULLETIN

Nederlandse Federatie voor Raketonderzoek

Nederlandse Federatie voor Raketonderzoek

Colofon

Het NERO-Bulletin is een uitgave van de Nederlandse Federatie voor Raketonderzoek.
Het Bulletin wordt toegezonden aan de leden van de aangesloten verenigingen en aan begunstigers van de Federatie.
Begunstigerschap van de Federatie kost f 45,- per jaar.

Correspondentie-adres

Nederlandse Federatie voor Raketonderzoek
Secretariaat
M. Tromp
Aquamarijnlaan 234
3523 EP Utrecht

Redaktie-adres

Kouwerplantsoen 67
3571 LW Utrecht

Bestuurssamenstelling

Voorzitter	B. Ouwehand
Seceretaris	M. Tromp
Penningmeester	J. Koster
Coördinator veiligheid	F. den Boer

Aangesloten verenigingen

NERO Eindhoven
Secretariaat Kuilenhurk 22, 5512 CB Vessem

NERO Haarlem
Secretariaat Wolstraat 7, 2011 ZA Haarlem

Betalingen

Postgiro 3000824
t.n.v. Penn. Nederlandse Federatie voor Raketonderzoek, Utrecht

NERO op Internet

http://www.nerorockets.org

Geregistreerd bij de Kamer van Koophandel voor Oost-Brabant onder nummer 40.23.59.78

ISSN 1382-2187

Inhoudsopgave

Aan dit nummer werkten mee:

J. Koster, B. Ouwehand, M. Tromp, W. Wegereef

Op de voorpagina: statische test Penta-1000 motor (1997)
Foto Jeroen Louwers

Gedrukt op een Kodak Ektaprint 30
Oplage: 100 exemplaren

NLC-3, NERO lanceercampagne op donderdag 10 en vrijdag 11 juni 1999, ASK ‘t Harde

Programma

Op donderdag 10 en vrijdag 11 juni aanstaande zal er, ter gelegenheid van het 40-jarig bestaan van NERO, een tweedaagse lanceercampagne worden georganiseerd op het Artillerie Schietkamp ASK in ’t Harde bij Oldebroek, met een groot aantal raketten uit binnen- en buitenland. Op dit moment zijn er 11 raketten van de NERO, 3 van de Deense DARK, 2 van de Vlaamse VRO, 1 van de Deense TuneGroup, 1 van het Summercampus van de Universiteit Twente en 1 van Doug Gilmore aangemeld.

Barbecue

Op donderdagavond zal na afloop van de lanceringen een barbecue worden georganiseerd in de onderofficiersmess, waarvan de kosten f 20,- bedragen. Iedereen kan zich hiervoor opgeven bij de secretaris, na overmaking van het bedrag aan de penningmeester.
NB: omdat NERO 3 weken van te voren aan het ASK moet opgeven hoeveel personen aan de barbecue deelnemen, en voor dat aantal moet betalen, verplicht men zich enerzijds door het opsturen van het formulier tot betalen, en kunnen anderzijds de kosten, als men onverhoopt verhinderd mocht zijn, helaas niet gerestitueerd worden.

Aanmeldingsprocedure

Bezoekers die de campagne willen bijwonen kunnen kiezen of ze één dag of allebei de dagen willen komen; de kosten zijn gelijk. Voor slaapgelegenheid kan helaas alleen voor leden van de operationele teams gezorgd worden.

- Aanmelding voor **NERO-leden en begunstigers**:

Men dient zich voor 17 mei aan te melden bij de secretaris Maarten Tromp, per post: Aquamarijnlaan 234, 3523 EP Utrecht, of per telefoon: 030-2534379 (overdag) of 030-2895916 (’s avonds), of per email: m.tromp@bs.uu.nl. De toegangskosten zijn al inbegrepen bij de contributie. Als het goed is hebben de leden en begunstigers vorig jaar reeds de permanente verklaring van vrijwaring (disclaimer) ingeleverd; dat hoeft dus dit jaar niet meer.
Deelnemers aan de barbecue moeten voor 17 mei het betreffende formulier opsturen naar de secretaris, en de kosten overmaken aan de penningmeester.

- Aanmelding voor **introducés** op uitnodiging van een NERO-lid of begunstiger:

Men dient voor 17 mei de verklaring van vrijwaring (disclaimer) in te vullen en op te sturen naar de secretaris Maarten Tromp, Aquamarijnlaan 234, 3523 EP Utrecht. Tegelijk maakt men de toegangskosten van f 10,- over op girorekening 3000824 t.n.v. “Penn. Nederlandse vereniging voor raketonderzoek” te Utrecht, onder vermelding van “NLC-3”. (Bij betaling op het Artillerie Schietkamp bedragen de toegangskosten f 15,-)
Deelnemers aan de barbecue moeten bovendien voor 17 mei het betreffende formulier opsturen naar de secretaris, en de kosten overmaken aan de penningmeester.

#

FORMULIER VOOR DEELNAME AAN DE BARBECUE OP DONDERDAG 11 JUNI

naam

adres

wil deelnemen aan de barbecue op donderdag 11 juni en zal de kosten van f 20,- overmaken op girorekening 3000824 t.n.v. Penn. Nederlandse Vereniging voor Raketonderzoek te Utrecht.
Voor 17 mei opsturen naar Maarten Tromp, Aquamarijnlaan 234, 3523 EP Utrecht.

Overview of projects for NERO Launch Campaign on 10,11 June 1999

Status per 1 May 1999, compilation by B. Ouwehand

	H7E NERO Haarlem		**H8** NERO Haarlem	**U18** NERO Eindhoven	**Flying Saucer** NERO Ehv. L.van Vliet
General					
Length and diameter (cm)	2204 x 10		*159* x 10	153,5 x 8	30 x 50
Mass at lift-off (kg)	13,2		*8,2*	5,1	1,4
Type	Two-stage Experimental		Single-stage Experimental	Single-stage Experimental	Experimental
Motor data	1st stage	2nd stage			
Type	Penta-alfa2	Penta-500	Penta-1000	Penta-1000	cigaret burner
Propellant composition	AP/PU	AP/PU	AP/HTPB	AP/HTPB	KN/sorbitol
Propellant mass (kg)	1,125	0,30	0,525	0,530	0,29
Total impuls (Ns)	2104	520	1040	1040	300
Burning time (s)			1,2	1,2	23
Recovery system data					
Type	Single-stage	Two-stage	Single-stage	Single-stage	N.A.
Release	Lateral hatch	Lateral hatch / sleeve	Lateral hatch	Axial nose cone	N.A.
Descent velocity (m/s)	18	pilot: 33 main: 10	*10 – 15*	*12*	N.A.
Trajectory data					
Tower exit velocity (m/s)	26,9	26,9	*37*	47	N.A.
Maximum velocity (m/s)	143	154	*135*	215	< 10 (hor.)
Apogeum altitude (m)	886	1944	*880*	1420	< 30 (vert.)
Apogeum time (s)	13,5	22	*13,5*	17	-
Parachute eject time (s)	13,5	pilot: 21,5 main: 63	*13,5*	17	-
Touch down time (s)	53	100	*72 – 101*	*137*	ca. 23
Impact range (m)	300	900	*300*		< 100
Rocket systems					
Flight control	Digital timer	Finite state machine	RDAS pyro output	RDAS pyro output	Thrust vector control (+/-5^o) and gyro attitude stabilization
Data acquisition	-	RDAS: P, a, 3x gyro	RDAS: P, a, 3x gyro	RDAS: P, a, gyro	-
Experiments	-	gyro, separation+ rec.system	canard control about pitch axis; validation aerodyn. model	cross-wind sensitivity	Microcontr., 2x servo, 2x gyro, 3x accel.
RF link	-	beacon 144 MHz	beacon 144 MHz	beacon 144 MHz	-

Note: RDAS = Rocket Data Acquisition System
Preliminary data are in Italics

	Muren-3 DARK	**Mjölner** DARK	**SmallTom-3** DARK	**Aurora** TuneGroup	**Golden Sky** VRO
General					
Length and diameter (cm)	165 x 7,5	*120* x 5	186 x 12,7	92 x 10,2	314 x 16
Mass at lift-off (kg)	6,3	*ca. 3,4*	27,7	5,0	25,0
Type	Single-stage Experimental	Single-stage Experimental	Single-stage Experimental	Single-stage Experimental	Single stage Experimental
Motor data					
Type	Composite	ZnS	ZnS	Composite	Caribou / VOX-5
Propellant composition	AP/epoxy/add.	Zn/S	Zn/S	KN/sorbitol	KN/sug/sorb.
Propellant mass (kg)	1,1	*ca. 1,0*	8,6	1,8	4,3
Total impuls (Ns)	1770	*540*	3200	1600	5300
Burning time (s)	3,8	*0,8*	0,5	2,5	3,2
Recovery system data					
Type	Single stage	Single stage	Single stage	Single stage	*Single stage*
Release	Rocket separation	Rocket separation	Rocket separation	Rocket separation	Lateral hatch servomotor
Descent velocity (m/s)	*ca. 20*		11	12,3	*8,3*
Trajectory data					
Tower exit velocity (m/s)	28	*35 (@ 2 m)*	*44 (@ 2 m)*	31,3	26 (@ 4 m)
Maximum velocity (m/s)	260	*190*	140	333	192
Apogeum altitude (m)	2739	*1110*	900	2219	1770
Apogeum time (s)	23,7	*15,5*	13,4	19,1	19
Parachute eject time (s)	30 (@ 2548 m)	*16*	13,6	35 (@ 1160 m)	19
Touch down time (s)	157		94	129	*211*
Impact range (m)	960	*500*	300	1100	650
Rocket systems					
Flight control	Timer			Timer	Digital timer
Data acquisition	Solid-state data collector			-	-
Experiments			*Video camera (under investigation)*	Motor qualification	Motor qualification and new mechanical construction
RF link	Downlink 433,92 MHz / 10 mW		TBD	-	-

Notes: Mjölner data based on NLD 94 subscription
Preliminary data are in Italics

	Ignis Volans alfa NERO Hlem. F.de Brouwer	**Ignis Volans beta** NERO Hlem. P.Fakkeldij 60%	**Ignis Volans gamma** NERO Hlem F.de Brouwer	**Thunder and Lighting** NERO Haarlem	**n.n.** TU-Twente Summercampus
General					
Length and diameter (cm)	240 x 10	260 x 10	260 x 10	219 x 6,9	234 x 10
Mass at lift-off (kg)	3,0	3,5	4,0	3,8	*5,0*
Type	Single stage HPR	Single stage HPR	Single stage HPR	Two-stage HPR PML-kit	Single stage HPR
Motor data					
Type	Aerotech I-435W	Aerotech J-570W	Aerotech J-570W	1: J-350W 2: J-350W	Aerotech J-350W
Propellant composition	AP/HTPB/Al.	AP/HTPB/Al.	AP/HTPB/Al.	AP/HTPB/Al.	AP/HTPB/Al.
Propellant mass (kg)	0,277	0,527	0,527	1: 0,375 2: 0,375	0,375
Total impuls (Ns)	600+/-5%	1046-1060	1046-1060	1: 700 2: 700	700
Burning time (s)	2,0	2,0	2,0	2,0	2,0
Recovery system data					
Type	Rocket Man two stage	Rocket Man two stage	Rocket Man two stage	1: single stage 2: two stage	Rocket Man two stage (R24D, R9C)
Release	pilot: axial main: axial	pilot: axial main: axial	pilot: axial main: axial	1: axial 2: streamer main axial	axial nose cone
Descent velocity (m/s)	pilot: 56 main: 12 – 13	pilot: 56 main: 12 – 13	pilot: 56 main: 12 – 13	1: 14 2: streamer 56 main 14	
Trajectory data					
Tower exit velocity (m/s)	29,6 (@ 2 m)	27,5 (@ 2 m)	26 (@ 2 m)	20,8 (@ 2 m)	
Maximum velocity (m/s)	149	206	187	1: 80 2: 310	ca. 120
Apogeum altitude (m)	695	1120	1055	1: ? 2: 2158	ca. 800
Apogeum time (s)	11,1	13,7	13,7	19	ca. 14
Parachute eject time (s)	pilot: 14 main: 22 (baro 200 m)	pilot: 14 main: 30 (baro 200 m)	pilot: 14 main: 29 (baro 200 m)	streamer: 20 main: 55 (baro 200 m)	drogue: main: (baro 300 m)
Touch down time (s)	35	46	45	69	
Impact range (m)	300	500	450	1: 100 2: 1000	ca. 250
Rocket systems					
Flight control	Adept ALTS-25 altimeter	Transolve P5 altimeter	Transolve P5 altimeter	2nd stage ign. Transsolve 2TT timer, Adept ALTS-25 altimeter	RDAS pyro outputs
Data acquisition	-	RDAS: P, a	RDAS: P, a	-	RDAS
Experiments	system test			two-stage test	Al-structures, video camera
RF link	-	-	-	-	Downlink 1,3 GHz, 2 W FM

	Endeavour NERO Ehv. W.van Bergen	**Sandia Sandhawk** NERO Ehv. W.van Bergen	**Sentinel** NERO Ehv. Bert Koerts	**n.n.** Guest Doug Gilmore	**VL-2** VRO
General					
Length and diameter (m)	179 x 10	172 x 7,6	200 x 10	ca. 1,6 x 10	155 x 10
Mass at lift-off (kg)	4,2 *(or 3,7)*	1,7	ca. 4,9	ca. 2,5	11,0
Type	Experimental *(or HPR-kit PML)*	HPR-kit	HPR-kit	HPR	Experimental
Motor data					
Type	54/1280 casing + AP/HTPB *(or 38/720 + reload J-350W)*	cluster 2xG80 + 2xG33	38/1080 J-570 W reload		VOX-2
Propellant composition	AP/HTPB	AP/HTPB	AP/HTPB		KN/sug/sorb.
Propellant mass (kg)	0,660 *(or 0,375)*	0,25	0,53		1,874
Total impuls (Ns)	1280 *(or 700)*	4x120	1060	600 – 700	1924
Burning time (s)	2,5 *(or 2,0)*	4,0	2,0		2,9
Recovery system data					
Type	Two stage	Single stage	Single stage		Single stage
Release	Rocket separation + axial nose cone	Rocket separation	Rocket separation		Lateral hatch servo motor
Descent velocity (m/s)	pilot: 25 – 35 main: 6	10-15	10-15		8
Trajectory data					
Tower exit velocity (m/s)					17 (@4 m)
Maximum velocity (m/s)	< 300 *(or 180)*	< 250	< 200		144
Apogeum altitude (m)					984
Apogeum time (s)					14,7
Parachute eject time (s)					14,8
Touch down time (s)					120
Impact range (m)					343
Rocket systems					
Flight control	RDAS pyro outputs	motor delay charge	motor delay charge		Analog timer
Data acquisition	RDAS: P, a	-	-		-
Experiments	-	-	Carbon fiber body		-
RF link	-	-	-		-

Notes: PML = Public Missiles Ltd.

H8 Project outline

By Bernard Ouwehand, NERO-Haarlem

Introduction

Project H8's goal is to build a rocket with controlled fins that is able to correct disturbances in trajectory caused by cross-wind, mis-alignment etc. In order to get familiar the the various technologies required to build such control device it will be necessary to divide the project in phases. Each phase has to be concluded succesfully before continuing with the next phase. Below, a project outline is presented and also a description of the configuration for the first flight, intended to be performed on the NLC-3.

Project phases

First phase includes model simulations of a fin controlled rocket and the validation of these models by means of one or more flights. On these flights the fin control is activated only after burn-out of the rocket motor. This guarantees that trajectory deviations due to failure of the control system are minor and safe recovery is possible. Initailly, only single axis control will be demonstrated, later two and three axis control. This phase also serves to demonstrate the soundness and rigidity of inhibit- and fail-safe mechanisms that are needed to maintain safety under all practical circimstances.

Second phase includes closing the loop in the fin control system. Flights will have to demonstrate that certain commanded attitudes c.q. orientations can be acquired and maintained during the flight. An example is stabilization of roll rate after lift-off. During the second phase fin control is active only after burn-out of the motor.

Third phase implies that the control system is active during the propelled phase, instead of after burn-out. This makes it possible to perform corrections for cross-wind influence, and as a result of that also a more predictable trajectory, and a higher probability of safe recovery.

Configuration of H8 first flight

It is intended to have the first flight of the H8 project on the NLC-3. We have imposed the following requirements on the design of the rocket:
- motor burning time as short as possible (minimizes controller inhibit time and maximizes experiment time).
- measurement of rotation about 3 axes, acceleration in flight direction, atmospheric pressure
- geometry and mass properties typical for NERO rockets.
- open loop single axis fin control (actually canard control), expandable to multi-axis system.
- results of fin control experiment shall be translatable to future 'third phase' flights.
- relatively simple single stage recovery system.

Some requirements are imposed by practical limitations. For example, the gyroscopes that measure rotation have a range of +/- 90 degrees per second. Therefore the experiment shall not invoke angular velocities exceeding that value or the sensor signal will turn into saturation and information on absolute orientation about the corresponding axis is lost. Furthermore, the rocket motor with shortest burning time and relatively highest thrust is the MEROC Penta-1000. For locating the fin control system a minimum of 100 mm diameter is required. Together with the requirement to have a 'NERO representative geometry' this results in a rocket mass in the range of 5 to 10 kg, a maximum velocity between 110 and 150 m/s and an experiment time of at least 10 sec.

All these considerations lead to the following configuration for the H8 (status per April 28):

- Lenght	1,60 m
- Diameter	100 mm
- Mass at lift-off	8,2 kg
- Motor impuls	1040 Ns
- Burning time	1,2 s (composite AP/HTPB)

Trajectory data:

- Maximum velocity	130 m/s
- Maximum altitude	800 m

Specification of rocket systems

Rocket motor
The H8 will be boosted by a MEROC composite motor, type Penta-1000. This motor has a relatively short burning time of only 1,2 seconds in combination with a moderate total impulse of approximately 1040 Ns. It is qualified in various flights of the U-series rockets and has never failed so far.

Recovery system
This is based on the proven design of other Haarlem rockets. A pyro bolt ejects a lateral hatch and releases a cruciform parachute. Descent velocity on the parachute is 10-15 m/s. The pyro bolt is activated by the timer output of the newly developped RDAS module from AED (see website information). Lift-off is detected using a breakwire and/or by means of the build-in acceleration sensing function of the RDAS module.

Data acquisition
The RDAS module is provided with three external gyro sensors of the type Murata ENC-05, These have a range of 90 deg/s which is more than the calculated worst-case angular velocity about any axis of the rocket, during the fin control experiment. The RDAS module samples standard acceleration and pressure, which allows reconstruction of the major trajectory data (velocity and altitude as function of time). Furthermore, relevant parameters in the fin controller such as battery voltage and statuses will be measured.

Fin controller experiment and aerodynamics
Single pitch axis control is performed using a pair of canards (front fins), driven by stepmotors. The motor control circuit is provided with a microcontroller that commands a sequence of deflection angle setpoints as a function of time. A description of the canard controller and associated circuit is given in a dedicated article in this Bulletin. The aerodynamic design of the H8 rocket, the modelling and the theoretical basis of the fin controller experiment is explained in a dedicated article by Wim Wegereef in this Bulletin.

H8 canard controller design

By Bernard Ouwehand, NERO-Haarlem

Introduction

The canard control experiment of the H8 consists of a mechanical aspect (the canard, torque motor and mounting/alignment), an aerodynamics aspect (geometry of the rocket inclusive fins and canards, calculation of moments and forces), and an electrical aspect (motor controller, safe/arm/inhibit, power provision). Below, the focus will be on the electrical design aspect of the experiment and the motor selection criteria. For the pitch axis control two identical canards are mounted at opposite sides of the rocket body. Each canard is controlled by a dedicated motor. Canard deflections are (for this experiment) programmed to be always in the same direction.

Design drivers and trade-off

Major design drivers for the canard controller are:
- Worst case torque te be delivered by the motors, and the duration of pre lift-off condition.
- Size, dimension and mass constraints for the motors.
- Accuracy and speed of the motors.
- Fail/safe operation.

Typically, for modern fin controller systems, electrical servo actuators are used. Servo actuators are compact, closed-loop modules comprising an (electrical) motor and associated gearbox, position/speed sensing device (potmeters/encoders) and an electrical control system that makes the motor drive meet a given position or speed setpoint. Cheap, compact and lightweight servo actuators are widely used in RC model cars and aircraft. Unfortunately, a review of the specifications of these servo's points out that they are not particularly suitable for application as canard controller in the H8. Main objections are: (i) they have too large backlash (measured up to 2°) in the gearbox, (ii) the potentiometers are potentially sensitive to vibration and form part of the control loop, thereby increasing the risk of noise/spikes, (iii) the high accuracy devices that are available are too big to fit in the half diameter of the rocket body. (iv) they are controlled by analog pulse with modulation circuits that are basically inaccurate and sensitive to drift and noise. Professional servo's are very expensive c.q. not affordable and home-designed servo's require complex mechanical construction.

For the H8 an alternative type of motor has been chosen, namely a stepmotor. Each canard is directly mounted on the rotor of a stepmotor. The stepmotor is driven by a dedicated stepmotor power control circuit. Advantages of the stepmotor relative to the RC servo's are: (i) very accurate positioning and positioning stability (better than 0,1°),(ii) very fast stepping, typically 1,8 degree in 5 ms, (iii) simple microprocessor control by providing discrete cw/ccw clock pulses. The stepmotors also have a number of characteristic disadvantages: (i) there is no absolute feedback of angular position so if power is lost, the absolute position is lost or at least unknown, (ii) in order to maintain position the coils or 'phases' have to be powered continuously with requires a high amount of on-board stored electrical energy. These disadvantages are compensated for by having redundancy in controller power.

Concept description

The figure 1 functional diagram shows the architecture of the stepmotor controller. The stepmotor is from Sany Denki, it is unipolar and delivers a hold-torque of at least 260 mNs

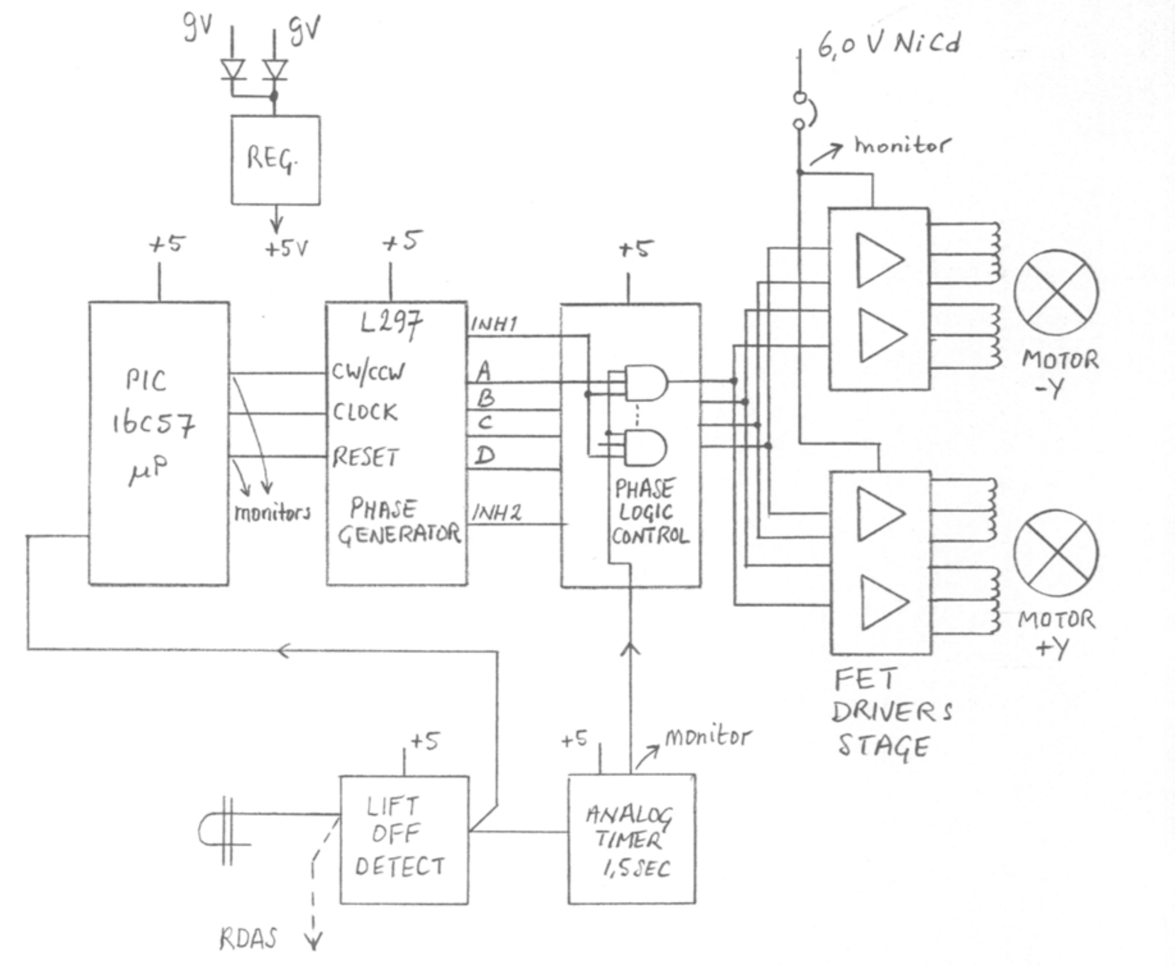


Figure 1

(measured 360 mNs) at a phase current of 1,2 A @ 3,6 V). Each motor has two phases and there are two motors, so the battery must be capable of providing 4,8 A current. The battery consists of five 1200mAh high capacity 'penligh-type' NiCad cells. Using very pessimistic assumptions, this battery still provides enough energy to power the motors for at least 10 minutes.

The driver stage for each motor consists of four power MOSFETS with low Rds(on). A well-known controller IC type L297 provides the phase switching signals for the MOSFETS. The L297 clock/reset/direction inputs are controlled by a microprocessor PIC16C57 (same type as used in H7 second stage flight controller). In between the L297 and the gates of the MOSFETS are logic gates that are part of the phase switching logic and allow overruling the L297 pulses with a canard inhibit or 'holding' signal. This signal is generated by an autonomous timer circuit that is triggered upon lift-off of the rocket and it forces the stepmotors to hold their position during powered flight. At the same time, the microprocessor maintains the hold-state during the rocket motor burning time. Upon calculated burn-out time, the microprocessor internal timer expires and the canard control experiment is initiated.

Experiment sequences

At the time of writing this article, it is not yet known what sequences will be used in the control experiment. Based on calculations and computer modelling, canard angular deflections of maximum 10 – 15 degrees (i.e. 5 to 8 steps) in both directions give well measurable and realistic pitch angle (alpha) variations. Typicall, the response of the rocket to deflection steps of various amplitudes can be measured, at various velocities. After burn-out the velocity of the rocket decreases at a rate of 10 m/s. Therefore the total experiment time is limited tot some 11 to 12 seconds. Upon reacing the apogeum, the experiment has to be finished, because parachute ejection is needed for safe recovery.

H8 aerodynamic design

By Wim Wegereef

Selection of configuration

After the decision to go for a rocket with a limited lifting surface control the first question arises: what kind of configuration do we like.
There are several possibilities:

- Canard control
- Wing control
- Tail-fin control

Canard control is a small lifting surface in the front area of the rocket. This means that a positive deflection or rotation of the canard (positive about the out-going hinge axis of the right canard looking in forward direction of the rocket) the induced aerodynamic force contributes to the main lift vector of the rocket.

Wing control is generally a larger lifting surface in the neighbourhood of the centre of gravity of the rocket. Advantage is that the main lift-vector can, more or less, directly be canted. However, since the forces are stronger, for the aerodynamic lift of the rocket, the accuracy of the control is much more sensitive. Moreover, due to these forces the hinge-moments might be more significant so that a powerful wing-control system will be required.

In case of a tail-fin controlled configuration the deflection of the surface will cause an aerodynamic force that will be in opposite direction with respect to the main lift vector, since the tail-fin is at the rearward side of the centre of gravity. This means that the aerodynamic force of the tail-fin should acting in a reversed direction compared with the canard at the front, in order to affect the same rotational motion of the rocket.

Since in case of the tail-fin controlled configuration, space is required to build-in the actuators, while at the same time the space would be necessary for the available propulsion system, it was decided to skip the tail-fin option.
For the wing controlled option the risk of having serious deviations in the main vector is much bigger than in case of the canard-configuration. Therefore in the first assessment process the canard-controlled configuration was selected.

Requirements

Now we decided on the type of configuration, it will be time to select some requirements that the rocket should fulfil. These are:

- Static aerodynamic stability with a global static margin of 1. This means that the resultant of the aerodynamic force will act on the body about one body diameter aft of the centre of gravity.
- A canard deflection should have the right effect. A small deflection must not affect large angles of attack, or the other way around, high deflections should not affect only small

angles of attack. A moderate ratio between angle of attack and fin-deflection angle (in trimmed condition) should be in the order of 1 or 2. This means that in trimmed condition a deflection of 1 degree should affect an angle of attack of 1 or 2 degrees.

Stability margin

Assuming a stability margin of about 1 is a direct indication for the rocket design. Since the pitching moment M is linear dependent on the normal force N we will have the following relation:

$$M = -(x_{cp} - x_{cg}) * N$$

where x_{cp} and x_{cg} are, respectively, the distance x of the centres of pressure and gravity on the body axis with respect to the body nose.
Describing the forces and moments in terms of coefficients without dimension:

$$N = \frac{1}{2}\rho v 2 * S_{ref} * C_N \quad \text{and} \quad M = \frac{1}{2}\rho v 2 * S_{ref} * L_{ref} * C_m$$

with ρ and v respectively, the air density and velocity, while S_{ref} and L_{ref} are the reference surface and length, the relation between pitching moment coefficient C_m and normal force coefficient C_N becomes:

$$C_m = -\frac{(x_{cp} - x_{cg})}{L_{ref}} * C_N$$

Roughly for small angles of attack these coefficients are linear dependent with the angle of attack. This can be expressed by using the derivatives to the angle of attack α:

$$C_N = C_{N\alpha} * \alpha \quad \text{and} \quad C_m = C_{m\alpha} * \alpha$$

So we obtain the relation:

$$C_{m\alpha} = -\frac{(x_{cp} - x_{cg})}{L_{ref}} * C_{N\alpha}$$

From this relation it is easy to see, that when the static margin is in the order of 1 and $(x_{cp} - x_{cg})/L_{ref} \approx 1$ (using L_{ref} as the body diameter) that:

$$C_{m\alpha} = -C_{N\alpha}$$

Going back to the design criterion, that the static margin is about 1, then we see that this implies for small angles of attack that the derivative of the pitching moment coefficient must have the negative value of that of the normal force coefficient. However, since the normal force as function of the angle of attack is mainly dependent on the body geometry including a first ‘guess’ of the tail-fins and the canards, a first order of magnitude for the required pitching moment coefficient can now be obtained.

By decreasing or increasing the tail-fin surface, the relation between $C_{m\alpha}$ and $C_{N\alpha}$ can be fine-tuned. During this iteration-process the canard surface should be kept constant.

Via this process a first estimation of the tail-fin configuration has been obtained. A next step will be the dimensioning of the canard surfaces.

Trimmed conditions

In order to derive the geometry of the canard we will look at the trimmed conditions of the rocket. The rocket will be trimmed when at a certain angle of attack the deflection of the canard is such that the resulting pitching moment is zero. So that, in such case, the rocket will intend to keep its angle of attack without being forced to rotate.

Again, assuming that for small deflection angles the influence of the generated pitching moment is linearly dependent on the canard deflection we can determine the relation for the C_m as follows:

$$C_m = C_{m\alpha}\,\alpha + C_{m\delta}\,\delta$$

where δ stands for the canard deflection and $C_{m\delta}$ is the derivative of the pitching moment coefficient to the canard deflection.
Now, based on the criterion that in a trimmed condition the resulting pitching moment should be zero (C_m=0), we will obtain a relation between the trimmed deflection as function of the angle of attack:

$$\delta_t = -\frac{C_{m\alpha}}{C_{m\delta}} * \alpha_t$$

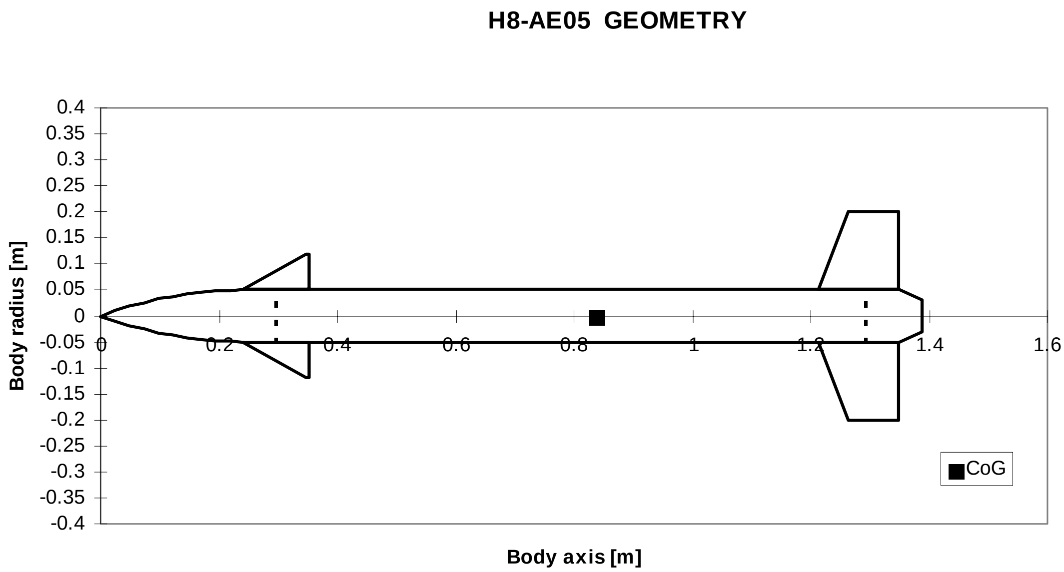
Since we have expressed the requirement that the relation between (trimmed) deflection and angle of attack should be in the order of 1 or 2 it is clear that the last equation will prescribe a relation between $C_{m\alpha}$ and $C_{m\delta}$. For instance assuming that this relation is about 1 ($\delta_t/\alpha_t \approx 1$) than

$$C_{m\delta} = - C_{m\alpha}$$

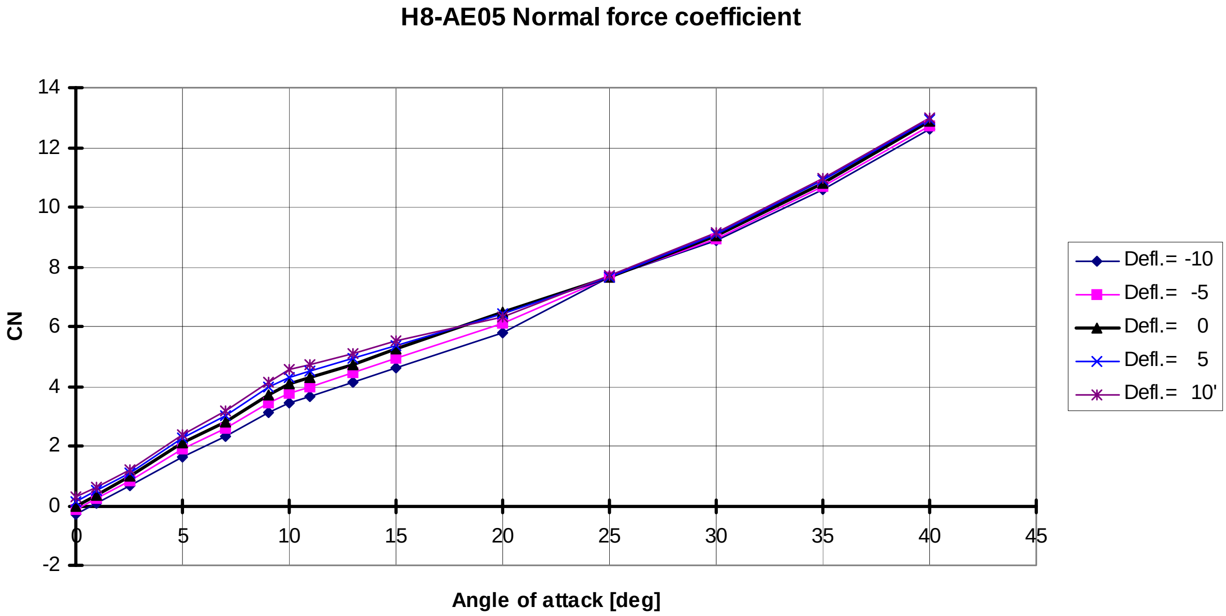
Again this is a clear criterion to dimension the surface of the canard.

A possible design

Using the foregoing process as a guideline then we have obtained a configuration of which the body geometry is shown below.
In addition the curves for the normal force and pitching moment coefficients are given as function of the angle of attack α.



The calculation of the aerodynamic coefficients are based on Mach = 0.6, while L_{ref} = 0.1 m, being the body diameter, $S_{ref} = 0.00785\ m^2$ is the body cross-section, and x_{cg} = 0.838 m with full motor mass and body length of 1.38 m.

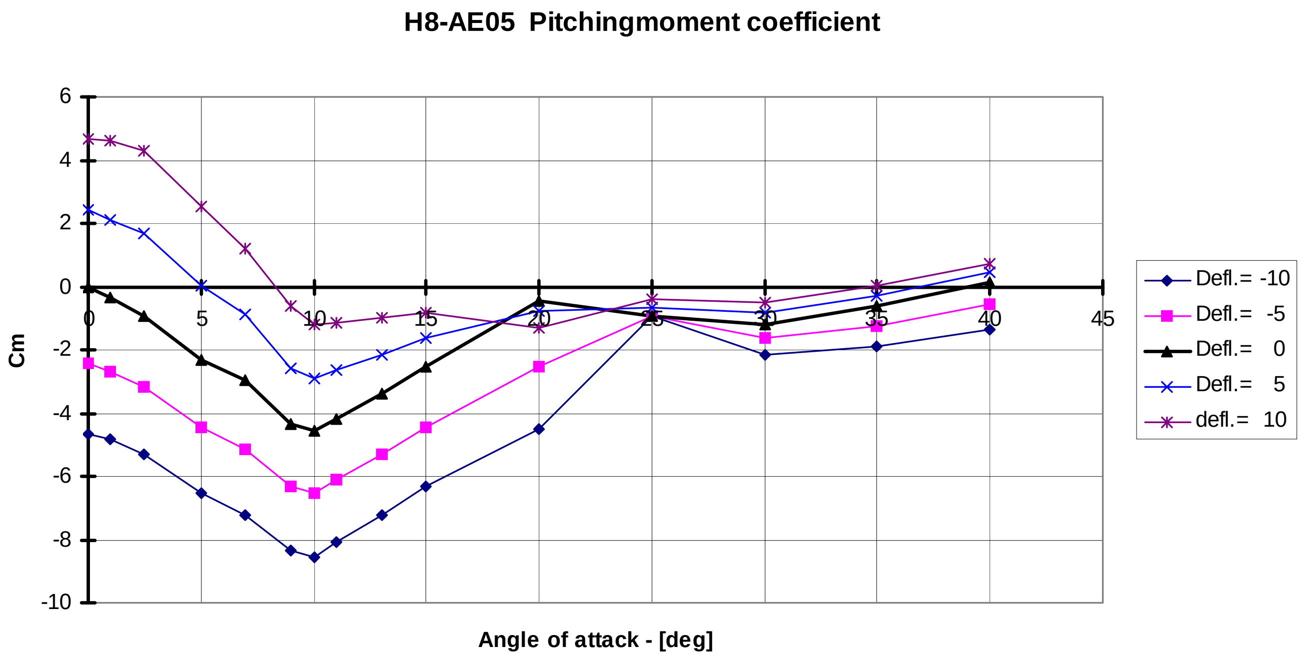


For comparing the result with the applied process we obtained the following estimations of the aerodynamic values:

$$C_{N\alpha} \approx \frac{C_N(\alpha = 10, \delta = 0) - C_N(\alpha = 0, \delta = 0)}{10} = \frac{4.077 - 0}{10} = 0.41$$

$$C_{m\alpha} \approx \frac{C_m(\alpha = 10, \delta = 0) - C_m(\alpha = 0, \delta = 0)}{10} = \frac{-4.535 - 0}{10} = -0.45$$

$$C_{m\delta} \approx \frac{C_m(\alpha = 0, \delta = 5) - C_m(\alpha = 0, \delta = 0)}{5} = \frac{2.4208 - 0}{5} = 0.48$$



Note that these values are based on non-linear effects of the aerodynamic coefficients. A final design will only be obtained in several iteration loops.

Verklaring van vrijwaring voor het bijwonen van de NERO-lanceercampagne van donderdag 10 en vrijdag 11 juni 1999 op het Artillerie Schietkamp ASK te Oldebroek

De aanvrager

naam:

adres:

postcode en woonplaats:

telefoon:

e-mail:

introducé op uitnodiging van:

verzoekt de NERO-lanceercampagne van donderdag 10 en vrijdag 11 juni 1999 op het ASK te kunnen bijwonen als introducé en verklaart:

1. dat hij zich realiseert dat het bijwonen van raketlanceringen en/of statische tests logischerwijs een risico met zich mee kan brengen ten aanzien van de integriteit van eigen persoon of bezittingen vanwege het experimentele karakter van de NERO-raketten en -raketmotoren;

2. dat hij jegens de NERO en Defensie en zijn leden/personeel afstand doet van alle aanspraken, die in verband met het bijwonen van of deelnemen aan de NERO-lanceerdag zijn ontstaan, en de NERO en Defensie en zijn leden/personeel in dat verband vrijwaart tegen aanspraken van derden, hun rechtsverkrijgenden en risicodragers, tenzij er sprake is van schuld of grove opzet van de NERO, Defensie, danwel zijn leden/personeel;

3. dat hij de wijze van uitvoering van de lanceerdag, zoals deze door de commandant van het ASK of de NERO wordt bevolen, aanvaardt, en alle aanwijzingen die door de commandant van het ASK worden gegeven, zal opvolgen of doen opvolgen;

4. dat hij het toegangsbewijs dat hem in antwoord op deze aanvraag door de NERO zal worden toegestuurd of verstrekt, op het terrein van het ASK bij zich zal dragen samen met een geldig legitimatiebewijs (paspoort, rijbewijs of VNG-kaart).

Getekend in op

Handtekening