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IMAGING EXPERIMENT ON BOARD THE NERVA-1 ROCKET VEHICLE

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Abstract: *In the present stage the development of the Romanian small orbital launcher NERVA comprises an extended kcnowledge of the flight conditions regarding mechanical loads and vibration, under which the on-board guidance and control equipment must work. The dynamic behavior is almost identical to the dynamic environment encountered with the current Volkhov weapons, due to the enheritage of the suborbital block mentained in the NERVA design. Direct in flight measurements of the full motion and vibrations of the strucuture during the booster powered flight of a modified Volkhov rocket was considered for these measurements. A genuine, preliminary inertial platform was built into the Astrionics laboratory at UPB and flown on board the Drone Rocket RT-759M on June 15, 2010, under the name NERVA-1 space experiment. It involevs a wide-angle digital camera for on-board broadcast and the results of this imaging experiment are described in the paper. The imaging was mainly targeted on estimating the angle of attack along the whole trajectory of the vehicle. The results are presented below.*
Key words: *On-board imaging, flight geometry, flight attitude*

1. INTRODUCTION

The *NERVA-1* experiment was performed on June 15, 2010 and consisted in the real flight measurement of the six degree of freedom motion of a drone rocket vehicle built by Electromecanica S. A. Romania, the partner of the NERVA project consortium, through simple modification of the military Volkhov anti-aircraft missiles of the Romanian Air Force. The drone, currently called “RT-759M”, is in fact a Volkhov vehicle where the second stage, the sustainer, is kept dry and this way not fired, with the first, booster stage as the only powering unit of the rocket (Fig. 1). A short flight trajectory within a range of 20 km is thus obtained, with an extension right enoughf to be used as a mobile target for the actual SA-2 missiles during annual training campaigns of the RAF at the Cape Midia NATO test range on the western Black Sea bank. A large payload is thus available in the fuselage of the second stage of the RT-759M rocket and a small, 200 grams payload consisting of the inertial platform, powering battery and TV camera were easily accomodated into this large space. The position of the TV set is on a 45º direction of sight, bacward looking, towards the nozzle exit of the solid motor booster and at 45º orientation between the transversal axes of the on-board referential. The basic observation is that the booster flight of the NERVA launcher (Rugescu 2008, Tache et al. 2009) and the mechanical loads are almost identical to those on RT-759M.

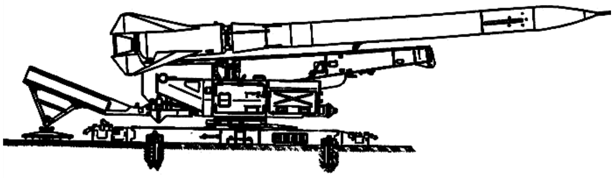

Fig. 1. RT-759M NERVA-1 on the launching rail

Worth mentioning that the NERVA-1 experiment is the first in-flight measurement and data telemetry ever performed in Romania and a tight plan of preparation was set-up in order to surpass the concernes regarding the reliability of the measuring equipment during this genuine test.

The paper is focused on presenting the results of the image processing for extracting the roll rate and the global attitude of the NERVA-1 vehicle during the powered and coast flight.

The nominal flight trajectory of the experiment extentded up to a maximal altitude of 7 km and with a total range of 18 km, into a launching vertical plane positioned at 112º geographycal azimuth over the Black Sea.

2. THEORETICAL CONSIDERATIONS

The paper is devoted to applying the methods of descriptive geometry and presents a graphic solution for the problem of finding the angle of attack of the rocket vehicle corresponding to each location on the presumed flight trajectory of the rocket. For this purpose we have to run through the following steps:

- to determine the coordinates u_i and h_i of the mass center at successive moments of time t_i recorded by the digital camera placed on-board the rocket vehicle;
- to determine the ellipse resulted at the intersection of the visualizing cone with the horizontal-projecting plane (plane of zero quota-Fig. 2);
- to determine the angle γ between the axis of the visualizing cone and the horizontal line;
- to determine the angle α between the longitudinal axis of the rocket during its descent through Earth atmosphere and a parallel to the *Ox* axis, in the current point on the trajectory.

A sample view from the onboard movie is given in Fig. 3.

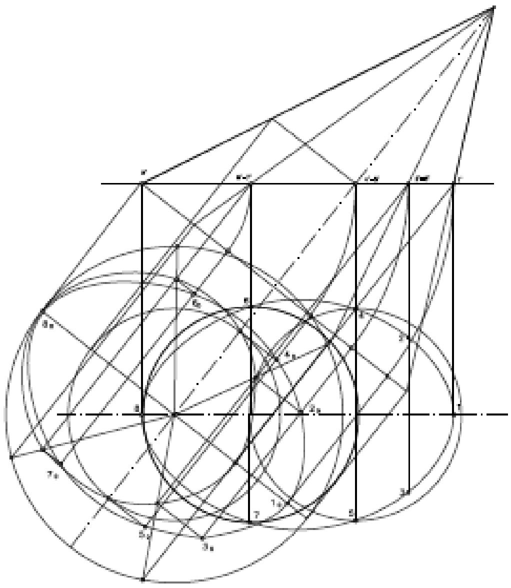

Fig. 2. Geometrical solution for the TV camera visual field

Fig. 3. Imaging frame at t = 2.9 s and 920 m altitude

The visualisation cone of the TV camera placed on the rocket determines in the horizontal-projecting plane:

- an ellipse when the plane intersects all the generatrices of the cone and yet is not perpendicular to the axis of the cone;
- a fragment of a hyperbola when the plane only intersects a few generatrices of the cone.

To build the horizontal projection of the ellipse a series of planes, perpendicular to the cone axis, are drawn, each of which intersects the cone along a circle and the horizontal-projecting plane in a horizontal perpendicular to the frontal plane. At the intersection of the horizontal projections of the horizontals with the horizontal projections of the corresponding circles, the current points of the ellipse are obtained.

The true size of the ellipse is given by the method of coincidence (Paré at al., 1997).

3. MEASUREMENTS AND RESULTS

Visual field of camera is a right circular cone with the tip angle of 60˚. By assumption, the roll axis of the rocket frame remains in the launching plane (Fig. 4). Images recorded by the camera during the flight revealed the following aspects (Fig. 5):

- the current position in respect to the launching site;
- time value at which this position is recorded;
- position of the cone axis (angle γ), determined by the vertex of the cone (the current point on the trajectory) and the center of the rectangular image of the TV camera.

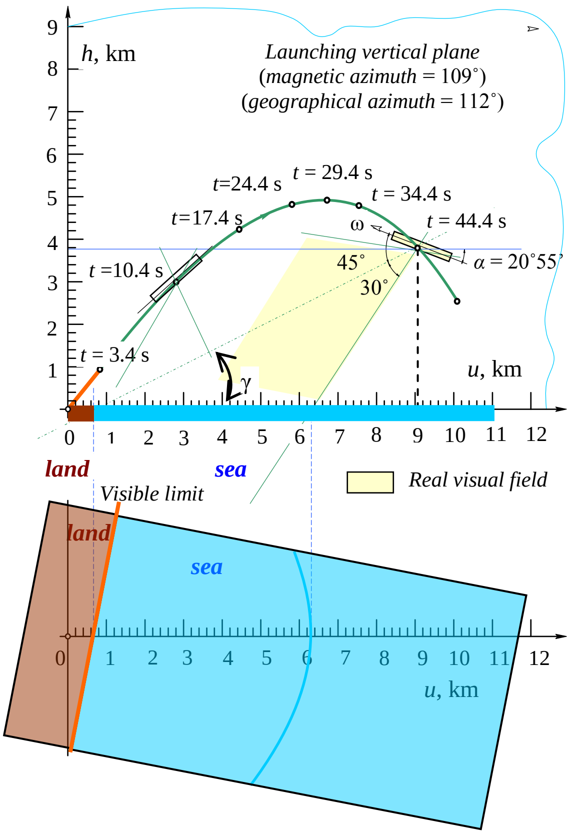

Fig. 4. Image processing at moment t = 44.4 s.

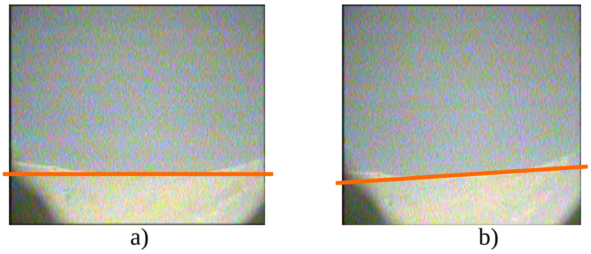

Fig. 5. Images at t = 34.21 s (a) and t = 34.32 s (b)

Equations that suply the inclination of the vehicle during its descent flight are:

$$\tan\gamma = \frac{h}{u_B - u_A} \quad (1)$$

$$\gamma = \tan^{-1}\frac{h}{u_B - u_A} \quad (2)$$

$$\alpha = 45^\circ - \gamma \quad (3)$$

The altitude and the corresponding angle of attack have been determined and entered in Table 1.

t [s]	u_B [m]	u_A [m]	h [m]	γ [˚]	α [˚]
34.21	7550	2100	4800	41˚20'	3˚40'
34.32	7550	2050	4750	40˚45'	4˚15'
44.4	9070	670	3750	24˚5'	20˚55'
45.11	9270	570	3600	22˚25'	22˚35'
46.05	9380	600	3540	22˚	23˚
54.91	10080	620	2500	13˚10'	31˚50'

Table 1. Results and measurements

4. CONCLUSION

The direct geometrical method applied to compute the attitude angle (angle of attack) of the flying vehicle along the trajectory proves simple and reliable, involving a minimal number of computational steps. The method is simple and fast enough to be considered for implementation into an automatic, real time procedure of attitude snesing during the whole plight of the orbital launcher NERVA.

The only problem that remains to be futher investigated and solved is related to the transmission reliability of the radio chain in order to cover a much wider range of up to 2000 km in horizontal direction for real-time data telemetry.

5. ACKNOWLEDGEMENTS

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