The Aguadilla airport case (04/25/2013)

1. Executive summary

The "2013 Aguadilla Puerto Rico UAP" report was submitted to the 3AF/SIGMA2 commission by the Scientific Coalition For UAP Studies (SCU) panel in May 2015, along with radar and video data. This report can be consulted via the following link : https://24d63f27-e686-40c4-adce-0870e805ceec.filesusr.com/ugd/299316_9a12b53f67554a008c32d48eff9be5cd.pdf

The report below exposes the in-depth study of a case of UAP observed at the Rafael Hernandez Airport site in Aguadilla, Puerto Rico, on April 25, 2013 at 9:20 p.m. (local time) based on the analysis of testimonies, the recording video and radar data.

The 3AF / Sigma2 commission set up a team of experts to conduct an analysis of the testimonies produced, the IR video data, the radar data and the SCU report which contains the environmental information relating to the event. The result of the analysis, carried out at the request and with the agreement of the SCU for the use of the data and the reproductions of images, is presented in this document. The main conclusions are as follows : It's not possible to determine with certainty what type of known object or phenomenon it may be - there is no convincing explanation for the oddities observed on the video recording - however, we can move forward :

- the radar returns recorded and the object filmed on the video cover distinct phenomena unrelated to each other,
- the radar returns probably correspond to cloud formations at low altitude,
- the object observed on the video appears to be emissive with a structure including a hot spot ; its main dimension is less than 1.3 meter ; its shape cannot be determined,
- it is not possible to determine with certainty the causes of the erasure of the image of the object, of its apparent impact with the sea, of its doubling,
- it is not possible to restore the precise trajectory of the object ; however, we can say that it cannot have a flight profile with stable parameters speed, heading or altitude, except for one case : that of an object drifting with the wind and descending slowly.

2. Avalable documents and data

Information reported by various witnesses

The testimonies cited in the SCU report were communicated to the investigators 6 months after the event by people in professional contact with the direct witnesses (DHC-8 pilot and crew, tower personnel). We notice some contradictions, especially in the timing of the sequence.

Radar data:

They were communicated to the SCU following the FOIA request made to the US Air Force. These are the Excel files of recordings made by 4 FAA civilian radars (no military radar data provided) during the 7 p.m. LT to 10 p.m. LT time slot on April 25.

The files provided indicate the coordinates of the radar returns, their date as well as the detecting radar, and the type of return (primary, secondary or primary + secondary) ; the altitude is specified in case of secondary return.

The video images have been recorded from the WESCAM MX-15D airborne imaging turret video output. The WESCAM MX-15D is mounted under the nose of an American DHC-8 customs and border protection (CBP). The system's infrared sensor operates in the MWIR mid-infrared band between 3 and 5 microns.

Figure 1

The recording makes it possible to visualize the infrared images of the UAP and of the background and, in overlay, a set of digital data :

- coordinates (x, y, z), heading, speed and attitude of the aircraft, returned from sensors and flight instruments of the aircraft,
- orientation of the camera (bearing),
- laser measured distance to target,
- coordinates (x, y, z) and azimuth of target, calculated from the above data.

3. Analysis of testimonies

The available informations[1] drawn from the reported testimonies allow to reconstruct the sequence of events :

- at the start of the CBP DHC-8 mission, the control tower asks the pilot "to go to the area north of the airfield to see if there is something unusual" ,

1 Especially at night, estimates of distance, linear speed, altitude of something we do not know how to identify are subject to caution; on the other hand, the angular dimensions (azimuth, site, angular width) are reliable.

- the pilot announces that he sees, through the left cockpit window, a pink-red light approaching, coming from the ocean, in a southerly direction; he locates it in the north-west of the aerodrome; he believes that the light is higher than the plane,
- the tower confirms that it also has visual contact and specifies that it has radar contact,
- when he considers it close to the coast, the pilot loses visual contact on the pink-red light,
- shortly after, the crew activated the onboard thermal imaging system to track the object.

The testimony of the control tower personnel is limited to very little :

- the DHC-8 crew is asked to "go and see": no precision is given in distance or azimuth to locate the radar contact ("to the north" is the only indication),
- the control tower confirms to the crew of the DHC-8 that he has visual contact and mentions that he has radar contact; we don't know what is done afterwards: does the control staff still watches the light? - Does they see it vanish, like does the pilot? - Does they perceive changes in the position of the light, azimuth, or elevation? - What is the behavior of the radar contact?
- an indirect witness mentioned the danger that the unknown radar contact would have represented, which would have justified the postponement of the take-off of the DC10 FEDEX 58 ; there is nothing to confirm this interpretation[2].

By crossing the testimonies with the radar data and data extracted from the video, we have reconstructed the probable chronology of the stages of the sequence of events. After takeoff at 9:16, the DHC-8 performed a first 360° turn by the left, passed again 2 km south of the runway, parallel to it ; then it performed a second 360° turn, during which it recorded the infrared image of the object (9:22) and finally moved south to resume the originally planned mission.

- It's probably during take-off that the tower asked the pilot to "go and see",
- it is likely at the end of the first 360° turn that the pilot sees the light "coming from the ocean", "north-west of the airport" ; "Shortly thereafter, the crew implemented the thermal imaging system" ; all these elements argue for locating the DHC-8 at point A (see figure 2) at the time the pilot announces the visual on the light, at point B when initiating infrared tracking.

2 However, the postponement of the take-off of the DC10 FEDEX 58 is likely, because the runway circuit is occupied by the DHC-8 which completes its first turn before spotting the UAP and then carrying out the infrared tracking : the tower cannot authorize the DC10 to take off at this time.

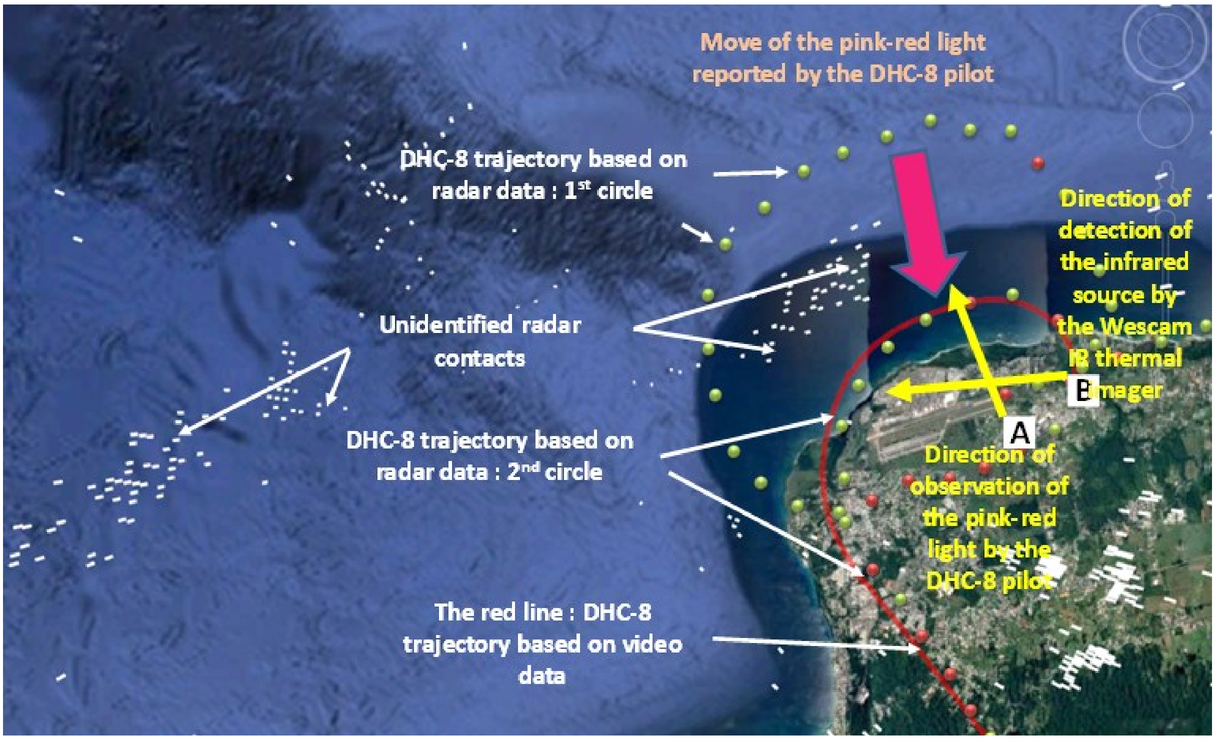

Figure 2

8:58 - Primary plots, detected by QJQ radar, appear on the control screen, initially 4 km north of the aiport (source: radar readings)

21:00 - Landing of Martinair MP 5713 from Bogota (source: traffic log)

21:16 - CBP DHC-8 takes off and performs a first left hand 360° turn north of the airfield (source : radar data)

21:19 - End of the first turn ; the DHC-8 flies about 2 km south of the terrain, parallel to the runway, and starts a second left hand turn (source : radar data)

21:22 – Beginning of video recording

21:25 - End of video recording

21:26 - Take off of DC-10 FEDEX 58 (source: traffic log)

The DHC-8 pilot loses sight of the light (it would have gone out, according to the witness). But it is possible that, the visual background no longer being the ocean but the land (we would be at point B), the light merges with other coastal lights and is therefore lost in sight.

The DHC-8 crew could not have noticed, on the thermal imaging system display, that the object seems to cross the runway twice: apparently they did not notify the tower.

Finally, we never simultaneously have :

- **visual observation and infrared detection of the object,**
- **radar contact and infrared detection.**

There is no evidence that the pink-red light observed and the infrared source detected and filmed on the video point to the same object.

The only possible indication of the position of the object is the intersection of the direction in which the pilot sees and locates the light in the north (at point A in Figure 2) and the direction in which the infrared source is detected from the point B : this point is very close to the airport, north of the runway.

4. Analysis of radar data

Unfortunately, could not obtain the detection data of the existing local military radar. Detections over the Aguadilla area come almost exclusively from the radar located at Pico del Este, 91.5 miles east of Aguadilla airport. The theoretical detection floor presented in the SCU report is 366 ft at the airport. In practice, it can be seen that DHC-8 is detected in primary mode as soon as it flies over the sea ; on the other hand, the primary detection is random, even rare, when the aircraft flies above the ground (observation made whereas the flight altitudes are higher than 2000 ft).

Throughout the area, we can notice a large number of unidentified primary plots.

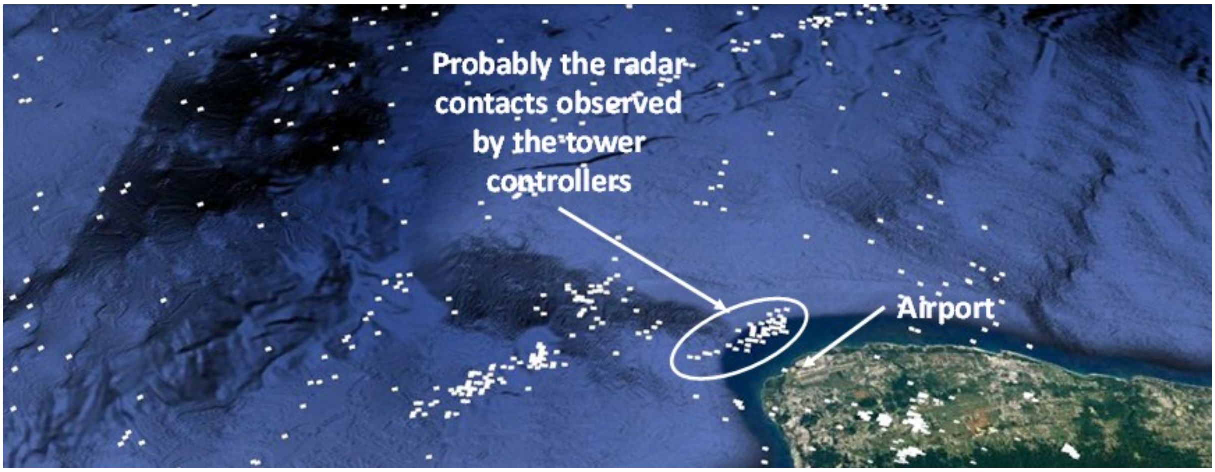

Fig. 3 - Primary radar contacts from 20:58 to 21:26 LT (white dots)

The plots move from the North-East to the South-West at a speed of 30 to 40 kilometers per hour ; their estimated altitude is between 200 and 600 meters. The meteorological data (significant cloudiness in April, 74% of the time, rain probability 30% of the time, between 30 and 70mm, wind direction mainly East and North-East) may cause moving stormy phenomena, driven by the prevailing winds over the sea; these phenomena are likely to cause radar echoes.

We ignored the few isolated plots that are only observed on one antenna turn : these plots cannot have worried the controllers.

The alert likely comes from the plots grouped in swarms (circled in Figure 3) to the northwest and west of the airport. Analysis of the radar data show that, in this swarm and in the one extending it to the west, only one plot can be seen per antenna turn, every 12 seconds.

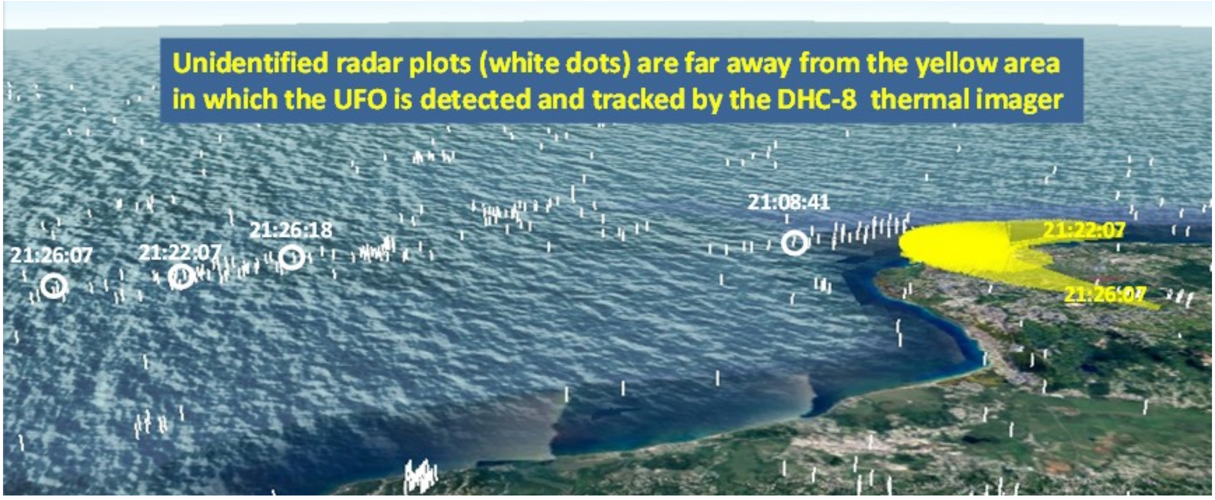

Fig. 4 – Successive positions of the echo which alerted the controllers

The trajectory of this plot is very erratic around an unmistakably well-defined mean direction (west / southwest) ; erratic positioning can be explained by the fact that radar echoes are generated by cloud formations, as mentioned above, and attach to density peaks. However, it is surprising to see only one cloud formation per antenna turn, as this formation is arguably not isolated. The hypotheses of a boat or a drone cannot be ruled out.

First primary plots appear at 8:58 PM, at about 4 km north of the airport. At the time of the DHC-8 take off (9:16 p.m.), the radar plots have moved westward more than 20 km from the airport ; they are even further away when the video recording starts : the radar plot positions of the plot do not correspond to the target positions returned by the video.

It can reasonably be deduced from this **that the event observed on radar and the event observed on the video recording are dissociated and cannot be attached to the same physical reality. They must be analyzed independently of each other.**

5. Analysis of video images - Radiometry

The detection chain is based on an FPA 640 * 512 detector (IRCMOS technology in InSb). Cooled to 77K, this detector has a spectral range between 1.5 and 5.5µm. Conventionally, a cold filter is added to it to make it work between 3 and 5µm (cf. Wescam documentation) which greatly reduces the effects of reflective radiation and ensures detection in the emissive range (typically beyond 2.5µm). An IrCmos conventionally has an output dynamic range of 10 and 12 bits, ie several thousand gray levels. At the output of the IrCmos, the signal is digitized in order to make the gain and offset corrections necessary to correct the response non-uniformities of the InSb technology. This gives a BSFR less than or equal to the temporal noise.

At this stage, it is possible to have a gain (manual or not) which adjusts the IRCMOS integration time in the frame time range to optimize the signal. The saturations seen in the video are unlikely to appear at this level.

After this correction, the signal (digital or analog?) enters the video keyer which aggregates navigation information, line of sight, etc. The purpose of the signal being to be viewed on an on-board monitor, there is no reason that the keyer works on a resolution higher than 8 bits and uses an AGC (automatic gain control) which reduces any hope of radiometry measuring. This is probably where the saturations appear.

The video we have is a digitization of a copy of the video (or more likely an analog recording) output from the monitors ; of very poor quality, it has a maximum of a hundred gray levels. This last step further accentuated saturations. In conclusion, the video we have has lost about a factor of 10 on the dynamics and a factor of 2 or 3 on the spatial resolution.

The video

We noticed an anomaly in the image below :

Fig. 5 – Contrast inversion

The shadow of the trees seemed more intense than the trees themselves. In fact, we are in reverse contrast; the pond reflects the sky which is cold, but the trees screen the sky, hence a strong contrast.

Impact of the moon

The moon's albedo is very weak (about 7%), and in thermal infrared, its emission is also weak ("equivalent" to a black body at 150 ° K). As can be seen in the figure below, even the full moon, which nevertheless corresponds to a type 1 night in BNL vision, has a negligible contribution beyond 2 µm compared to a background at 300K.

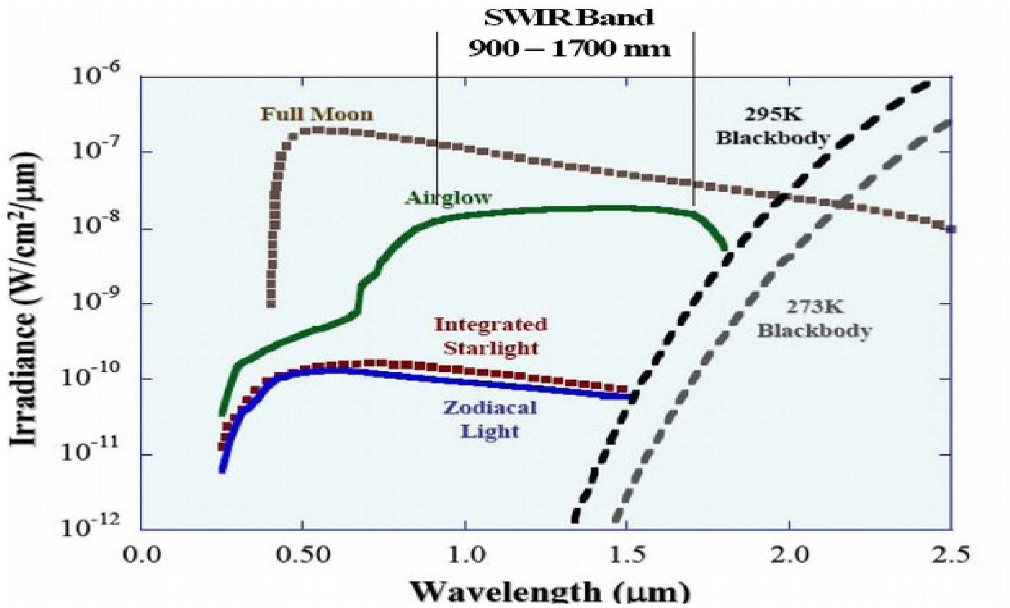

Fig. 6

Nature of the object

As we have seen previously, radiometric analysis is very difficult given the poor quality of the video. However, we can ask ourselves the question of the emissive or reflective nature of the object:

- If the object is supposed to be reflective, its signature will be strongly dependent on its shape, its environment and the angle from which it is observed. In particular, the reflection of the sky would result in a very low signature. All of this should lead to a signature that is weaker than the ambient (when it partially reflects the ambient 300K) or very weak (when it reflects the sky),
- If we take the hypotheses of a reflective spherical object, its signature should always be weaker than the ambient. If now we take the hypotheses of a faceted object, we should have a very fluctuating signature showing flashes.

We therefore conclude that the UAP appears to be emissive with a structure comprising a hot point. It is difficult to go further into the radiometric analysis of this video.

Concerning the shape of the UAP, the saturation as well as the very poor spatial resolution of the video do not allow us to give any indication.

UAP size

It can be evaluated from the angular field data available in the technical manual of the Wescam MX-15Di, which allows to know the opening of the visual for a given magnification, therefore to measure the angular size of the UAP; the maximum diameter of the UAP can then be calculated by considering that it is at the same distance as the target. The presence, on the video image, of elements whose metric dimensions are known (aircraft on the ground, width of the runway) validates this approach.

The values found are: 1.1 m to 8 km, 1.2 m to 6 km, 1.3 m to 4 km.

We can thus affirm that the maximum diameter of the object is of the order of 1.2 m, but that its apparent diameter increases slightly when the object is closer to the plane, probably because of the increase of its brightness.

Fig. 7 – On the left view, the target distance is 6300 m, the calculated size is 1.2 m – For 3900 m (right view), the size is 1.3 m, confirmed by comparison with the width (45 m) of the central strip of the runway – the maximum size is that of an object close to the target i.e. close to the ground.

Research of hypotheses explaining the temporary disappearances of the UAP on the video images

The occultation of the UAP, against a sea background, could be explained by the presence of clouds above 600 ft which would temporarily mask the object. However, we should also observe an obscuration of the sea background around the object, which is not the case. On a terrestrial background, some occultation images of the UAP also present partial occultations of the landscape, suggesting the potential presence of residual clouds at low altitude ; this hypotheses cannot be confirmed. The occultation could also be explained by the passage of the UAP behind the trees, which would allow us to fix a point of the trajectory. The sequence below illustrates this hypotheses.

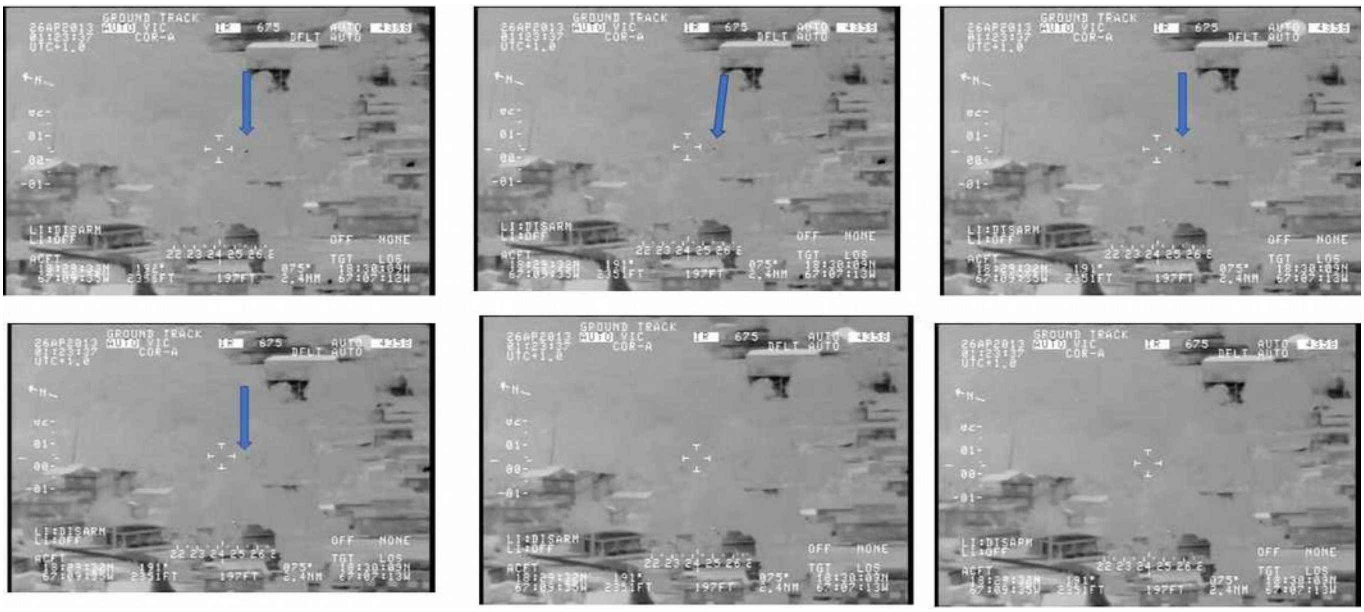

Fig. 8 – Transient occultation of the UAP infrared image

Research of hypotheses to explain the apparent impact with the sea

A strange "physical" phenomenon occurs when UAP appears to impact water. The explanation given in the SCU report refers to a phenomenon called Bernoulli's wavelet: the principle would be based on the effect of water displacement by the body moving underwater, which thus creates a ripple which rises towards the surface. As it rises, this wavelet expands and cools, which explains, according to the report, that the camera can follow a "cold" point in the water marking the position of the object. **However, we are in reverse contrast : a black point is a hot point and no longer a cold one!!** We do not know this effect and therefore cannot conclude, except for the fact that the water is not transparent to infrared radiation and therefore the camera cannot detect the submerged object if it is.

Fig. 9 – Impact of the UAP in the sea ?

We are not aware of any flying object, even in the case of a UAV of advanced design, capable of changing medium by diving into water at high speed. In any case, we do not observe any variation in speed which, for the objects that we know, would accompany changes in the environment.

Another possible hypotheses is sea-skimming flight with a surface effect projecting an “opacifying mist”. UAP masking occurs when it is very close to the water making a kind of ricochet ; the hot spot that appears would only be the fugitive thermal footprint of the UAP on the water.

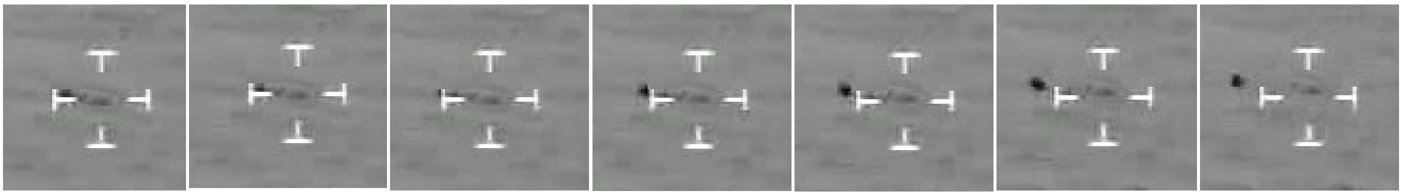

Fig. 10 - Successive views at t=24mn41; these views can be interpreted as a ricochet of the UAP on the water or as infrared flashes

Duplication of the UAP image at the end of the sequence

The duplication phase at the end of the video sequence lasts 10.5 seconds (1:24:42 to 1:24:52) ; the angular distance between the 2 "objects" increases up to 0.044 degrees, which represents a minimum distance of 7 meters, and 60 meters in the hypotheses where the UAP and its hypothetical twin fly in the same horizontal plane at sea level.

Fig. 11

Several hypotheses have been formulated to explain the doubling of the object image :

- anomaly related to the image acquisition system with parasitic reflection (hypotheses questioned by the lack of attenuation of the reflected image),
- swarm flight of two drones in close formation, then temporary separation (physically possible scenario),
- rupture or duplication of the drone-type object upon impact on water,
- fata morgana type candling effect with refraction on cold air layers, but weather conditions and the possibility of infrared candling have not been demonstrated.

None of these hypotheses, all theoretically valid, can however be neither verified nor refuted.

6. Study of digital data from video images

The use of digital data makes it possible to draw trajectories of the DHC-8, the trajectory of target positions and the lines of sight (LOS) of the camera (from the aircraft positions to those of the target).

The word target (TGT on the video image) designates the object targeted by the camera. The coordinates of its position in space, which can be red on the video recording, are calculated from data collected by the optronic system, including the camera-target distance measured by the laser device of the Wescam optronic system.

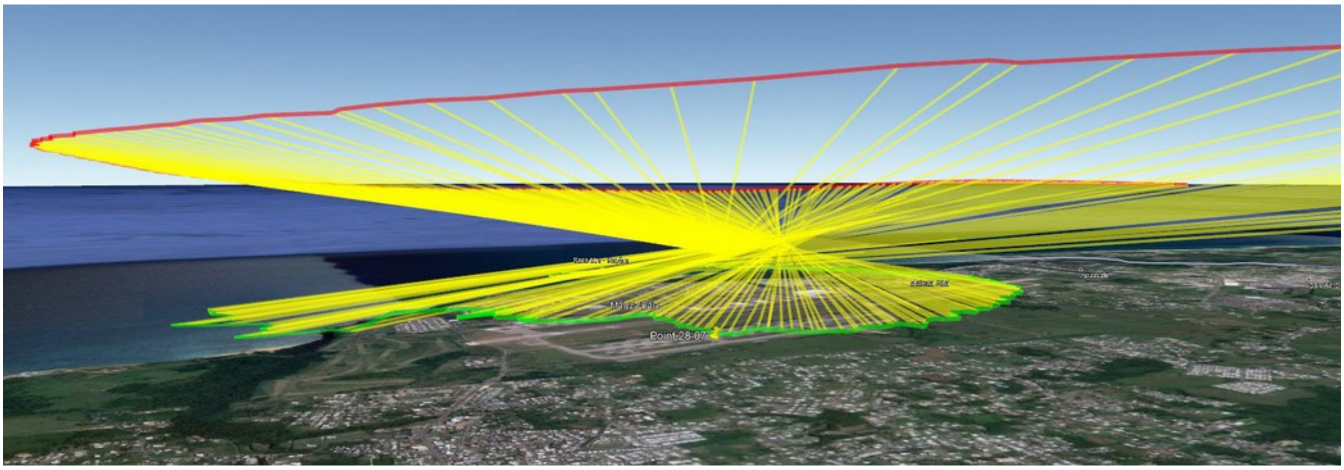

Fig. 12 – In red : trajectory of the DHC-8 ; in green : the target positions ; in yellow : the lines of sight

Analysis of the aircraft trajectory : the positions recorded on the video correspond perfectly (positions and timing) to those established from the radar data : this correspondence accredits the veracity of the testimonies and the authenticity of the video (see figure 2).

Analysis of the of target positions trajectory : the analysis of the coordinates and the altitude of the target clearly show that the target positions correspond to the ground points which are in the axis of the line of sight (LOS), in the background of the UAP : in fact, the laser beam does not hit the UAP, but the ground behind it. **The recorded target positions indicate the intersection of the LOS with the ground, not the UAP's position**.

The real airplane to UAP distances cannot be defined ; **it is not possible to deduce from the video the position of the UAP on the LOS, nor its speed, nor its altitude. We can only say that the projection of its trajectory is inside the yellow area swept by the lines of sight (figure 13)**.

Fig. 13 – The projection of the UAP trajectory is in the yellow area

The uncertainty about the real position of the UAP on the LOS leads one to be careful in in analyzing the video recording : we cannot be sure that the UAP trajectory really crosses the runway twice ; we cannot be sure that the UAP flies over the sea…

Moreover, the trajectory of target positions highlights the presence of several irregularities, particularly at the beginning of the video sequence (seconds 1 to 9, seconds 9 to 10, seconds 20 to 26), then further, at second 108 :

- seconds 1 to 9 : we can see several adjustments of the LOS elevation, resulting in significant variations of target distance,
- seconds 20 to 26 : the operator reduces the field of view (magnification is switched from 135 to 675) ; he must modify the camera site angle to maintain the UAP in the optical field of view and therefore changes the target position (the aimed ground point).
- seconds 9 to 10 and seconds 108 : there are significant variations of the target position as the laser beam hits the ground up and down the coastal slopes,

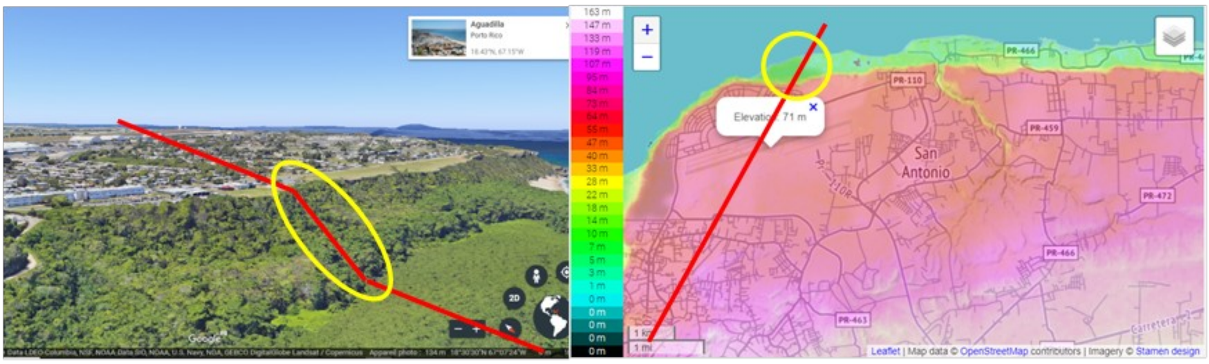

Fig. 14 – The steep slope of the terrain at the passage of the coast causes the important change of position of the point targeted by the camera and therefore of the laser distance

Optical tracking : video recording reveals an irregular scroll of the landscape scroll and horizontal jerks in UAP tracking (UAP seems to have sudden horizontal speed changes) ; the LOS bearing graph (dawn from video recording data) reveals steps, suggesting that the optical turret orientation is controlled by the airborne Wescam operator, not by an automatic tracking device.

Lines of sight : they present a very interesting characteristic regarding the development of possible UAP trajectories hypotheses ; indeed, all the lines of sight intersect in a narrow area close to the airport (see Figures 12 and 13).

The lines of sight are drawn from the data displayed on the video : they connect the aircraft locations to the target locations (the ground points behind the cross'hairs on the video pictures) : in order to elaborate relevant UAP trajectory hypotheses, we have readjusted the sight lines on the UAP by taking into account the value of the angular deviation between the cross'hairs and the UAP : the MX-15 specifications allows to draw a angular scale and, therefore, to measure the deviation.

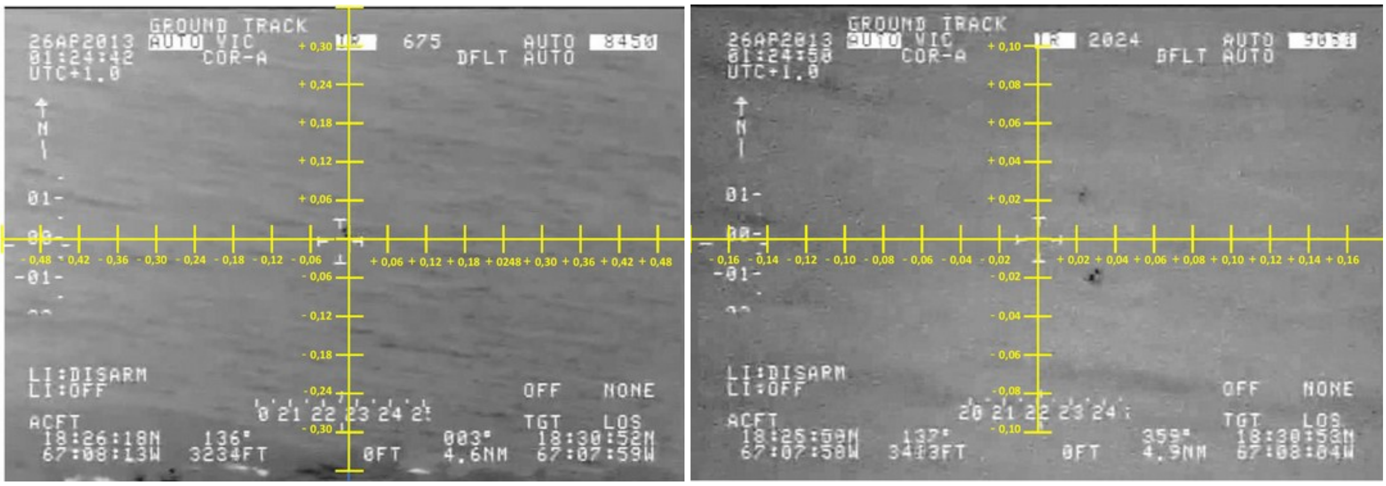

Fig. 15 – Construction of an angular deviation rating scale for 2 magnification values

This correction allows to build a new series of lines of sight.

We notice that, from second 5 to second 12, the target data displayed on the video recording is erratic, in particular regarding the longitude values : indeed, this can be explained by the unreliability of laser measurements on the indented coastline with a low elevation angle at 135 magnification rate. These data have not been taken into account in the calculations hereafter.

Accuracy of displayed data : the digital data recorded on the recording is not precise enough to produce useful analyzes of UAP trajectories ; in particular, target azimuth is given in whole degrees. This results in irregularities in the results of the calculations and therefore in uneven trajectories and graphs.

7. Search for consistent trajectories

The team of experts' approach consisted in considering the video recorded data to build potential UAP flight profiles which are consistent with the envelope of the lines of sight, in order to match their compatibility with known aerial vehicles types, in terms of performance or flight profile.

We therefore studied some remarkable flight profiles which could cover that of the UAP :

- profiles with typical behavior : formation flight with the DHC-8 , terrain following profile,
- vertical iso-speed profiles.

The consistency of the profiles has been studied from different points of view :

- consistency of trajectory from graphic representation,
- consistency of speed dynamics.

An ad hoc simulator has been used to generate the trajectories and the associated graphs.

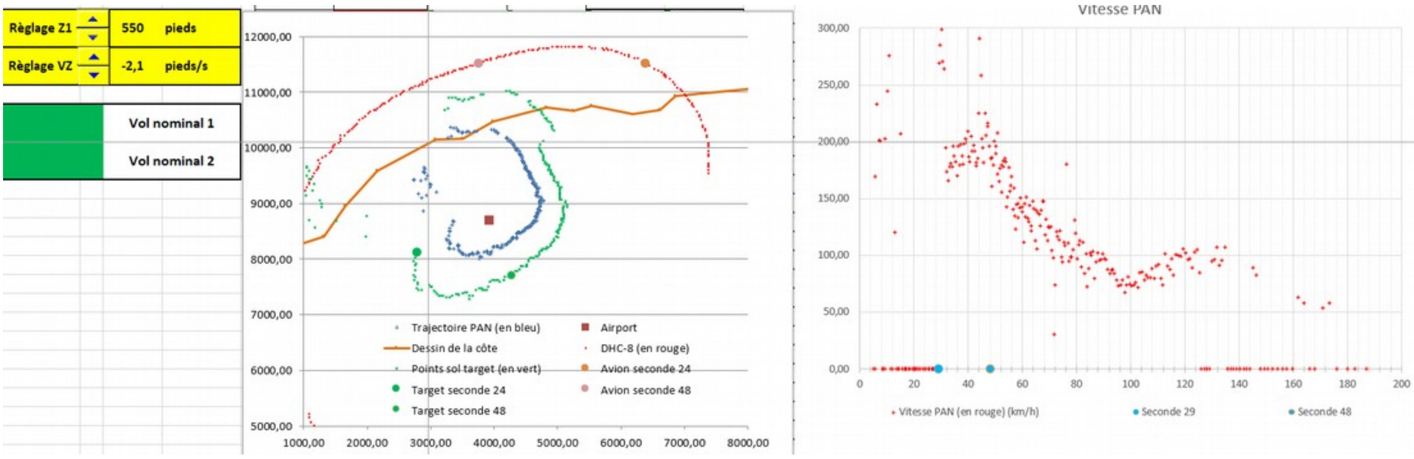

Fig. 16 – Simulator : in yellow, selection of Z1 and VZ, in green, indication of validity of the trajectory (checks that UAP is below DHC-8 and over ground level)

As a first observation, all the simulations confirm the left hand turn trajectory of the UAP around the airfield and the apparent coordination of movement and phase opposition with the DHC-8.

UAP speed is calculated from the values of its position coordinates ; but these values are widely dispersed due to the lack of precision of the video displayed data ; in order to obtain a controlled dispersion, UAP speed has been averaged on time periods covering 10 lines of sight (about 5 seconds at the beginning of the recorded sequence, 25 seconds at the end).

- Speed calculation method implies that the first interpretable value appears at second 10 of the recording,
- speed graphs as a function of time, show clouds of points which make possible to calculate averages,
- speed has been assigned the value 0 when it cannot be calculated.

7.1. UAP profile "in formation with DHC-8" (we arbitrarily set an altitude differential of -100 feet below the DHC-8)

Calculated position : UAP position at time t is the point of time t LOS with $Z = Z_{DHC\text{-}8} - 100$ feet.

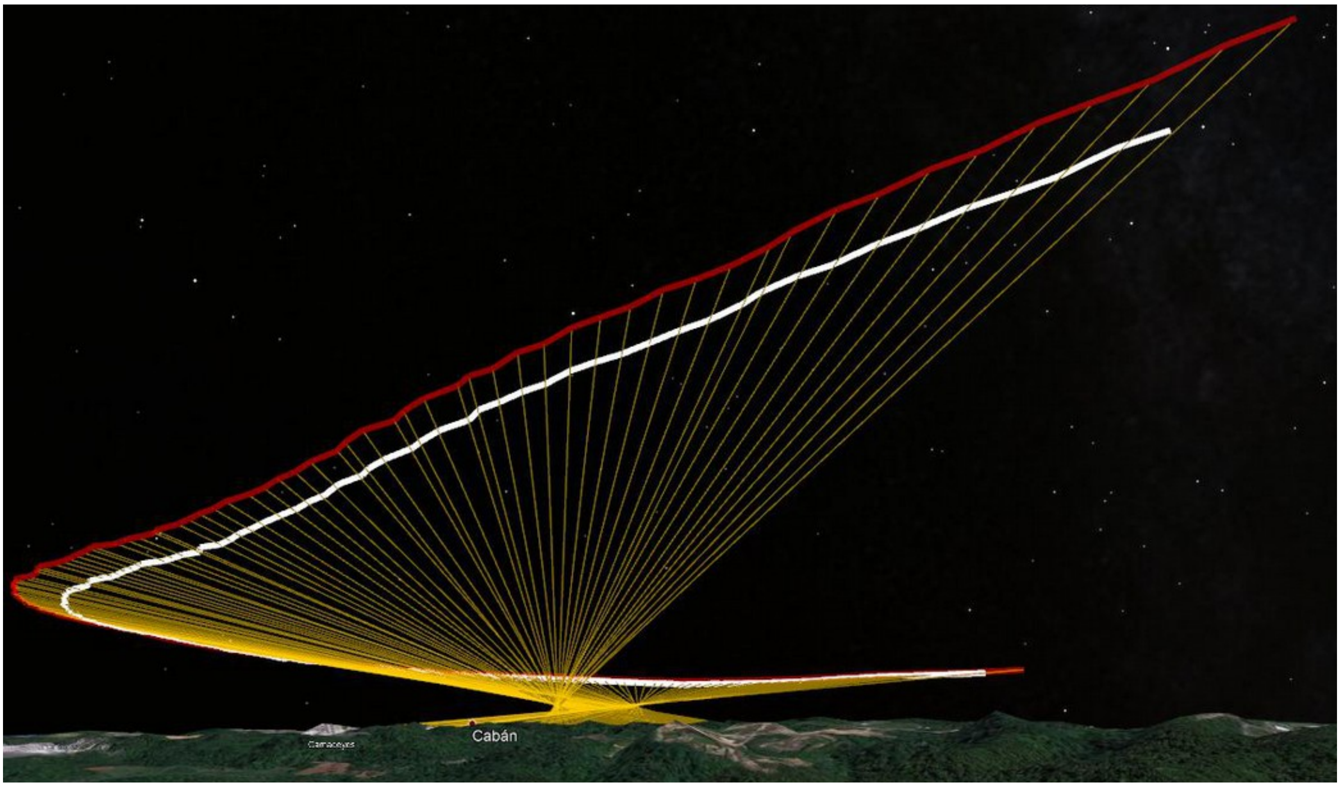

Fig. 17 – UAP trajectory (white) 100 ft below the DHC-8 (red)

- UAP flight parameters are very close to those of the DHC-8 ; they suggest UAP performance are similar to that of the airplane, particularly in terms of speed,
- this UAP trajectory is plausible from geometric and kinematic points of view.

7.2. Terrain following profile : this case is close to the hypotheses studied by the SCU. The UAP is close to the target ground points

The terrain following height has been set at 100 ft feet above the target points altitudes. UAP position at time t is the point of time t LOS with $Z = Z_{target} + 100$ feet.

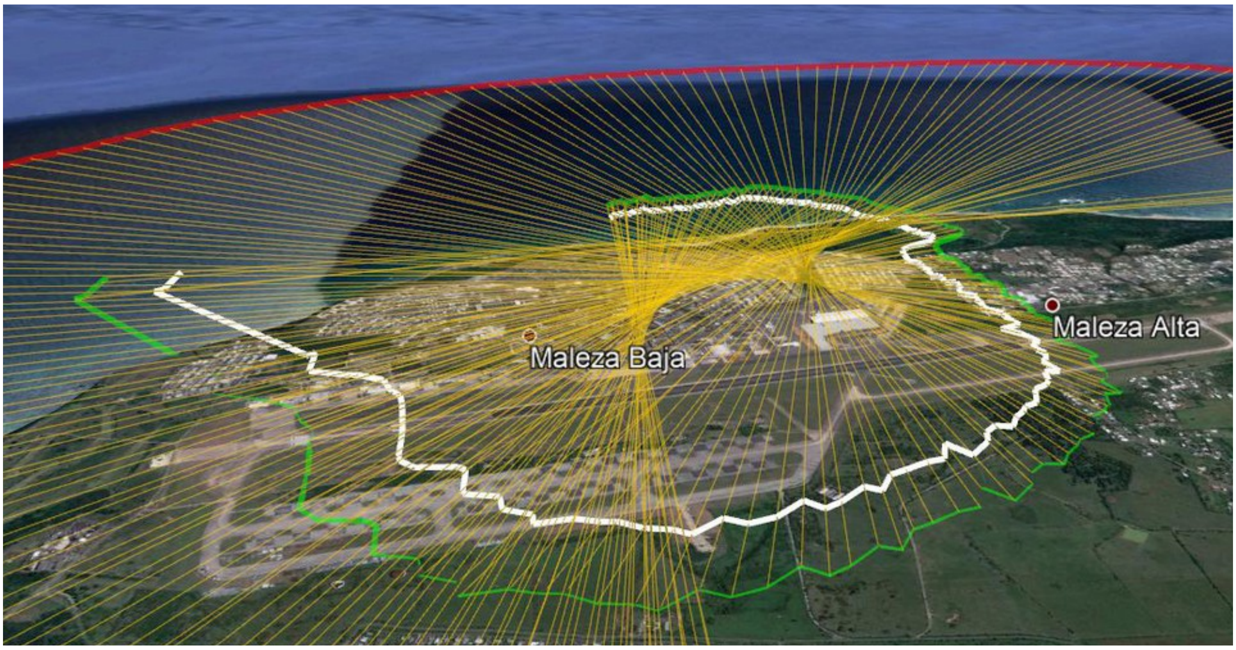

Fig. 18 – In white line : UAP trajectory in terrain following mode, Z = 100 ft

- the trajectory, close to the line of target positions, reproduces its irregularities,
- UAP speed is around 280 km/h from second 10 to second 48 ; it then decreases and stabilizes around 100/120 km/h ; it shows a gap at second 109, which can be explained by the crossing of the ground elevation step.

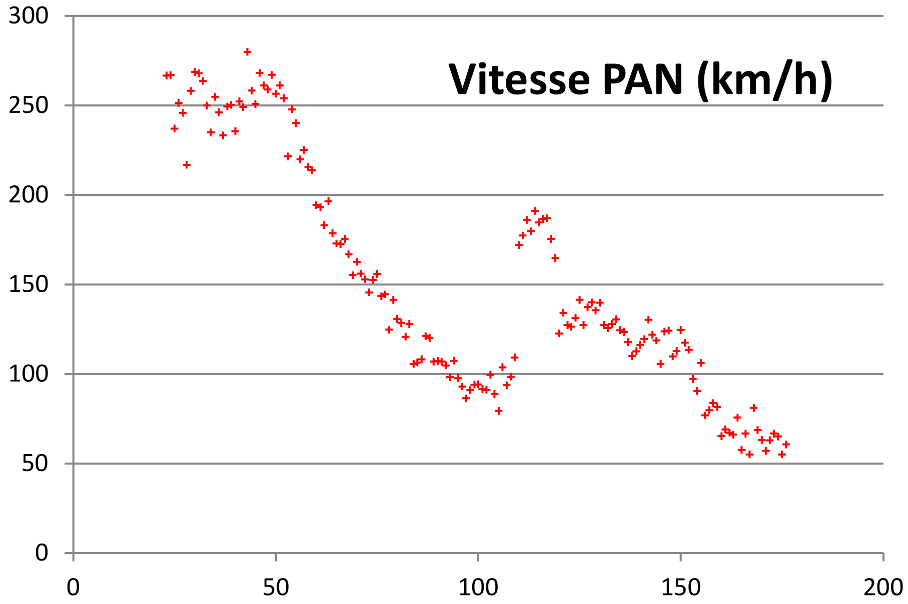

Fig. 19 – Speeds on the UAP trajectory in terrain following mode at height of 100 ft

The calculated trajectory and speed parameters do not provide significant information to validate or reject the hypotheses of a terrain following trajectory.

7.3. Constant vertical speed flight profiles

We studied these trajectory models by varying 2 parameters : the UAP vertical speed VZ and its altitude Z1 on the first line of sight (second 0 of the video recording).

The trajectories are iteratively constructed from the initial position of the UAP : the calculation of UAP position on LOS "n" is carried out from the position on LOS "n-1" by applying the altitude difference between “t-1” time and “t” time on the base of the considered vertical speed value.

The simulator (see figure 16) makes it possible to dynamically observe the transformations of the trajectories when Z1 and VZ are varied. We tested profiles associated with 52 (Z1, VZ) pairs : Z1 varying from 400 to 1600 feet and VZ from -8 to +10 feet/s.

The general appearance of the trajectories is a more or less closed curve, sometimes forming a loop.

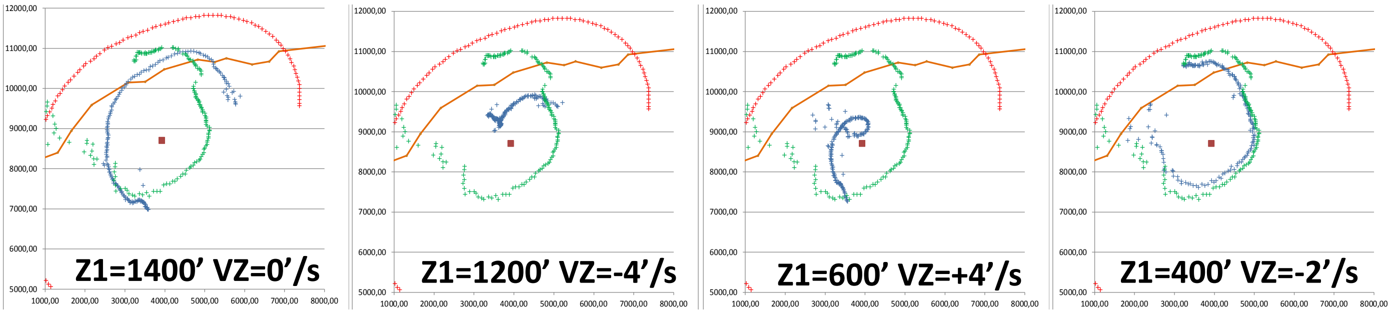

Fig. 20 – Constant vertical speed trajectory models (in blue)

None of the trajectories studied is incompatible with the performance of known aerial vehicles, but none allows favoring a particular hypotheses of profile or type of vehicle.

Speed profiles : for Z1 less than 1000 feet, the speed profiles show a peak of maximum speed, always around second 48 ; if Z1 is greater than 1000 feet, the peak occurs at second 52 : UAP speed increases between seconds 29 and 48, decreases and then stabilizes after having possibly gone through a minimum. The question of the reason for this peak around 48 seconds has not yet been answered.

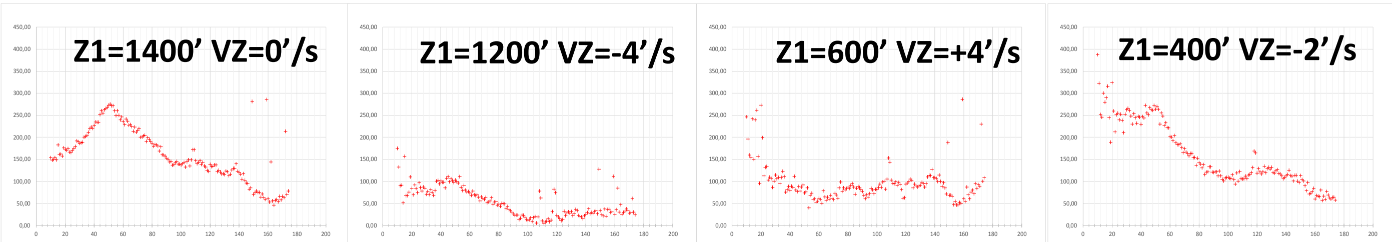

Fig. 21 – Examples of velocity profiles, corresponding to the trajectory models of Figure 19

The sawtooth shape attenuates and disappears when vertical speed values are comprised between -3 and +3 feet/s : UAP speed is stable, less than 100 km/h (between 30 and 80 km/h) and its altitude evolves around 850 feet (between 500 and 1,200 feet).

At the end of trajectory, speed values are always between 20 km/h and 180 km/h.

In conclusion, no trajectory model appears incompatible with the capabilities of known aerial vehicles. Some of the models, whose speed profiles are stable or show “reasonable” evolutions, may be considered as more plausible.

7.4. Focus on 3 specific trajectory profiles

We examine here 3 interesting profiles:

- iso-altitude trajectories, special cases of iso-VZ,
- a remarkable trajectory : straight route at steady speed UAP profile,
- trajectories compatible with impact with the sea:
  - first trajectory segment at a steep rate of descent, then low level flight above the land, then sea skimming and diving according to SCU,
  - or steep rate descent directly towards the sea, corresponding to what appears on the video recording.

7.4.1. Constant altitude trajectories :

When UAP altitude is constant, all trajectories end on land and are therefore incompatible with a possible impact with the sea ; speed dynamics have a variable profile (sawtooth more or less attenuated depending on the altitude) ; the speed values are contained within a range of 50 to 370 km/h ; when Z is less than 1200 feet, no trajectory overflies the sea.

These trajectories are theoretically plausible.

7.4.2. Straight route and steady speed trajectory :

For pairs of values (Z1, VZ) close to (1000 feet, -2 feet/s), the trajectory of the UAP is almost straight and parallel to the runway ; compared to other trajectories, it develops over a very short distance north and close to the airfield. The horizontal speed is steady, less than 50 km/h.

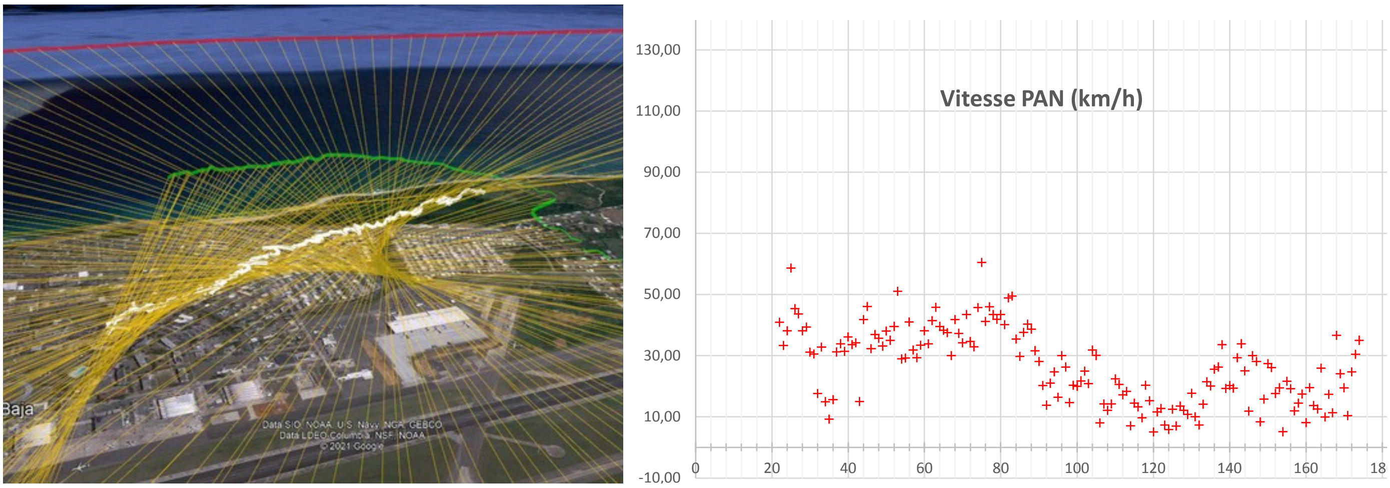

Fig. 22 – UAP trajectory for Z = 1000 feet, VZ = -2 feet/s

The stability of kinematic parameters gives a strong plausibility to this profile.

7.4.3. Plunging trajectory followed by very low level flight over the sea (with possible intermediate low level over land) :

If we suppose that the UAP ricochets on the sea or dives to re-emerge, its vertical speed on final must be low, which implies to pass the cliff (second 108) at a very low height : the vertical speed will be comprised between -4.3 feet/s (passing flush with the cliff) and -5.2 feet/s (passing at 40 feet over the cliff).

If we consider the vertical speed is constant (iso-speed)trajectory case, the Z1 altitude must be comprised between 640 and 780 feet.

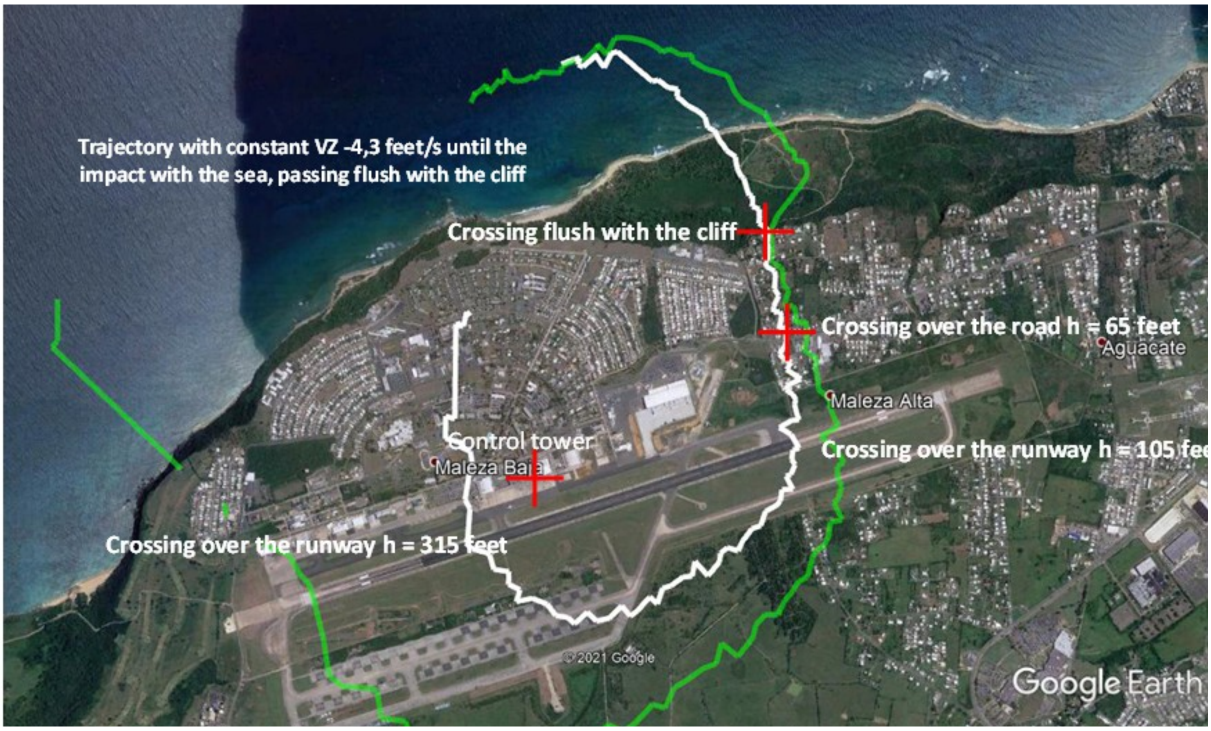

Fig. 23 – UAP trajectory for VZ = -4.3 feet/s

The speed profiles for the lowest and highest values of VZ are as follows :

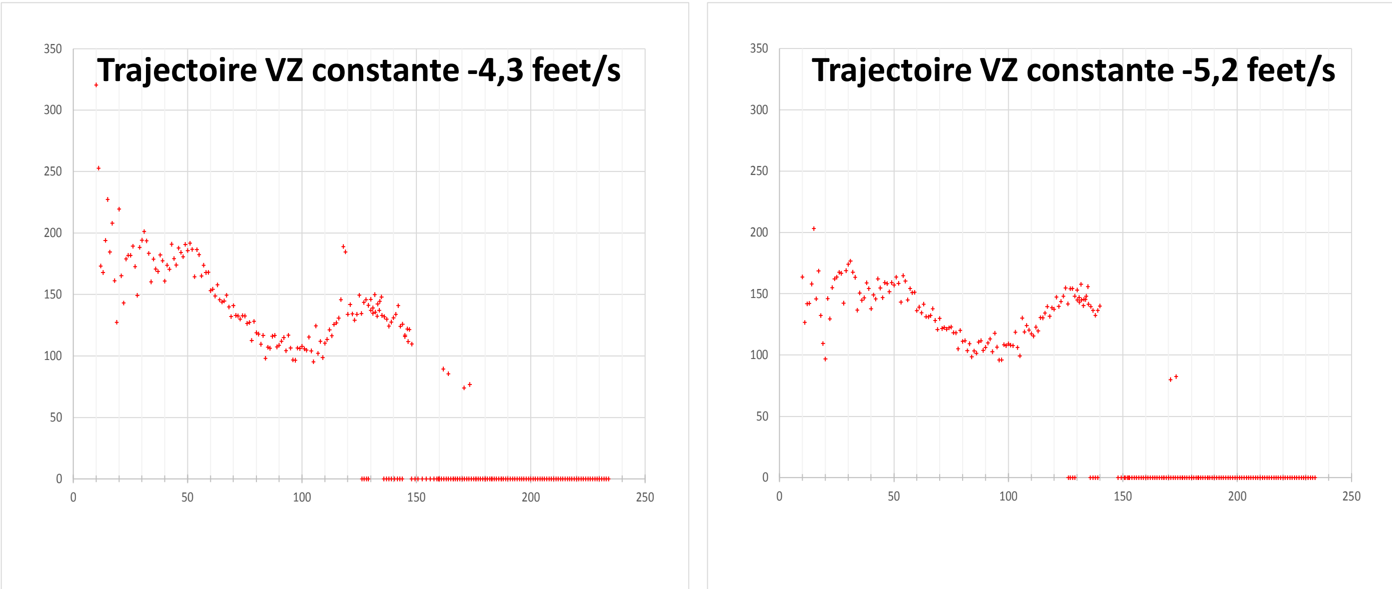

Fig. 24 – Speed profiles

UAP speeds are comprised between 80 and 200 km/h.

These trajectory profiles are theoretically possible. We can also imagine other flight profiles with higher vertical speed up to second 108, then decreasing when passing the cliff. The profile below is initialized from an altitude of 1800 feet with a VZ of -15 feet/s.

Fig. 25 – Trajectory with high VZ value at the beginning

This type of profile leads to strong speed variations : 300 km/h decreasing to 50 km/h before reaching the 100/150 km/h values range at the end.

8. Development and evaluation of hypotheses

On the basis of the trajectory models presented, several possible scenarios have been developed: they are presented below, and their plausibility is assessed with regard to their consistency with the technical elements available (radar detection, meteorological data), the events observed on the video, the testimonies collected, and finally their consistency in terms of operational credibility.

The aerial vehicles likely to be associated with the studied trajectories are listed in the following table ; only vehicles compatible of the metric size (<1.20 meter) have been listed ; a reference model has been chosen for each type of vehicle, specifying its performance.

	Représentative example	Ceiling (mètres)	Speed range (km/h)	Mode of propulsion	RCS (m²)	Size span/length (m)	Infrared emissive parts	Observed temp. (°C)
Thai lantern	Not applicable	600	Not applicable	Not applicable	?	Ø = 0,5	Heater	60
Micro drone*	DJI Phantom 4	6 000	0/72	4 électric engines	< 0,01	< 0,7	Engines + Battery	35/37
Mini drone	TTA America M 6A Pro	1 500	0/36	6 électric engines	< 0,1	Ø = 1,6	Engines + Battery	?
* Radio control range up to 8 km								

Fig. 26 - Conventional aerial vehicles

However, the speed requirements presented by certain profiles are incompatible with the performance of “conventional” micro and mini drones (see § 5.12.3.5 of the report and its appendix for more details on drones and § 5.2 for IR signatures). The listing of candidates has been extended to include drones such as the Racer X and those of the JetQuad family, capable of high speeds ; but these only appeared in 2016 for one and 2017 for the others, much later than the date of the Aguadilla case (2013) ! Without excluding the possibility that some type of prototypes could have been used, we must consider that the probability for solutions based on this kind of fast vehicles is very small.

They will be referred below as fast mini and micro drones.

	Représentative example	Ceiling (mètres)	Speed range (km/h)	Speed range (km/h)	RCS (m²)	Size span/length (m)	Infrared emissive parts	Observed temp. (°C)	Exhaust temp. (°)
Mini drone	Racer X	?	0/290	4 électric engines	?	?	Engines + Battery	?	Not applicable
Mini drone	JetQuad AB5	10 000	0/480	4 microturbos	?	1,2	Comb. chamber & exhaust	?	200/300
Mini drone	JetQuad AB6	10 000	0/400	4 microturbos	?	1,2	Comb. chamber & exhaust	?	200/300

Fig. 27 – Fast mini and micro drones : Racer X and JetQuad

Detectability considerations (visible light and infrared) :

- Electric mini drones and micro drones

They are the most "discreet" of the mobiles on the list ; small size (a few tens of cm), and above all, no internal combustion. Electric engines dissipate little heat. We therefore have a very low IR signature in band 2 and band 3, with an apparent temperature of 35°C to 45°C (depending on the band and the model) giving observation ranges of the order of one to several km. They are visible in daylight and the signature strongly depends on the paint used ; is very weak at night. To refine the detectability of the various vehicles (drones, lantern, etc.) by the aircraft's IR camera, a specific linkage analysis should be carried out, which has not yet been carried out.

- Jet propulsion scale models[3] or micro drones

Fig. 28 – Scale model (Rafale) and JetQuad

The propulsion is provided by one or 2 micro reactors.

The visible signature is low (strongly dependent on the paint, the jet signing is not very visible).

3 The model, although more than 1.20 meters in most cases, was presented for its exemplary value

The IR band 2 signature is very high because of the jet which extends over several tens of cm behind the nozzle (IR band 2 emission by the kerosene combustion gases ($CO2^{2}$, $H2^{2}O$, CO , ...)

In band 3, the IR signature strongly depends on the aspect angle ; the hot nozzle is the most significant element, therefore low signature of the front and side pats, and high signature of the rear. If the combustion is correctly regulated, there is little soot in the exhaust stream and therefore very little radiation from it in this band.

- The Thai lantern

Typical size is less than 1m. We performed SIR measurements on 2 types of lanterns of comparable sizes. The measurements are taken outside, but by retaining the lantern by a wire so as not to drop it in the Paris region. The measurements are carried out with a thermal camera band 3 and a thermo point which provides a poor quality image but a very good apparent temperature measurement. Some examples of the images obtained are given below.

A fairly high measured temperature (between 50°C and 60 °C) is observed and confirmed by contact measurements. As the lantern is captive, these measurements correspond to a maximum. However, these values must be reached for the lantern to fly. The ambient temperature was 4°C

The combustion of the fireplace lasts approximatly 5 minutes and the temperature rise takes between 30 and 60 seconds. On the other hand, the thermal inertia is very low (a few seconds) and the IR as visible light signature drops very quickly as soon as the flame goes out or if a gust of wind covers the lantern.

In summary, as long as the flame is burning, the IR signature of the lantern is significant and, at night, the visible signature is important ; but, as soon as the flame is extinguished, the visible signature disappears and the infrared signature collapses very quickly.

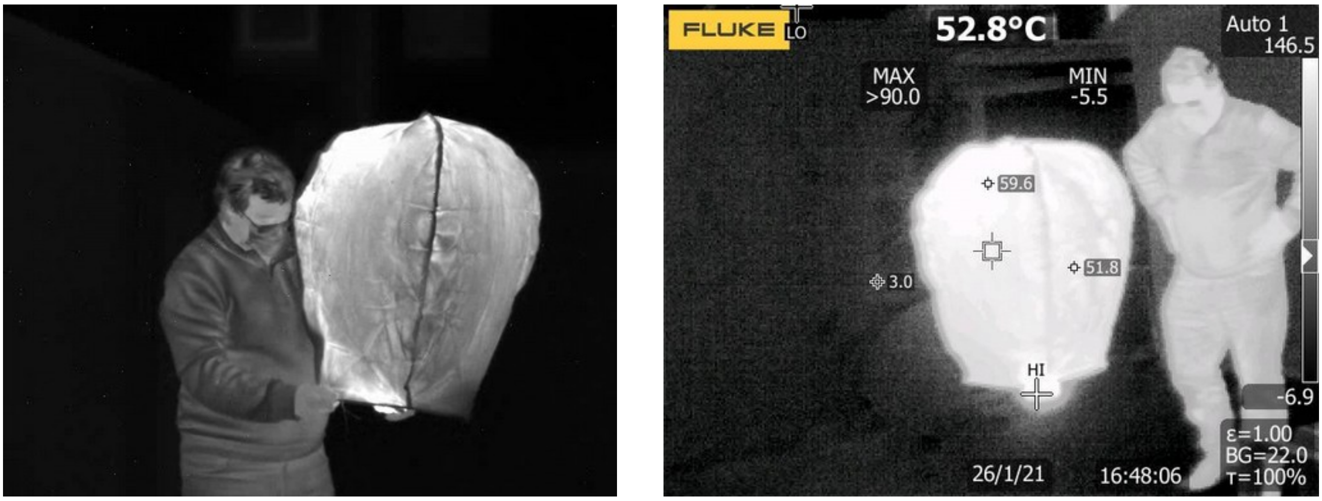

Fig. 29 – On left : example of band 3 IR image – On the right : thermo point image ; the temperature displayed at the top (52.8°C) corresponds to the center of the image, the 3 measuring points on the periphery give an idea of the dispersion

Taking these elements into account makes it possible to investigate the scenarios.

8.1. UAP in formation with the DHC-8 (Z_{DHC-8} – 100 ft) :

Staying in formation with DHC-8 implies a performance spectrum comparable to that of this aircraft : only fast mini and micro drones are capable of that.

Radar detection : radar data recording shows that, above ground, the DHC-8 is rarely detected as a primary contact ; so, it is no surprise that we do not detect the micro or mini drone whose radar cross-section is much less ; above the sea, where the detection is better, one can think that the drone should have been detected.

The infrared signature could be consistent with what is seen on the video images, but the disappearances and splitting are difficult to explain given the close proximity to the observer aircraft.

Staying in formation with DHC-8 excludes the hypotheses of a low level trajectory and of an impact with the sea.

Visual observation of a pink-red light by the DHC-8 crew : the pilot's observation of the light north of the aircraft is consistent with the scenario ; however, its disappearance, in the case of this scenario, can only be explained by the existence of a light device on the UAP (tracking, security?) whose operation would have been interrupted.

It is difficult to find a reason for a drone to accompany the DHC-8 at night.

In conclusion, the likelihood probability of this profile is very low.

8.2. Terrain following profile (flight height below 100 feet)

The speed range calculated on the trajectory (between 90 and 280 km/h) limits this profile to fast micro or mini drones.

Considering the altitude, it is not possible to comment on the consistency with radar detection.

There is no marked inconsistency in the infrared signature with respect to the engines of these drones.

The disappearances of the UAP image could correspond to local low-altitude cloud formations (related to ambient humidity) that we can guess on some images, but it is not possible to confirm or deny that. The hypotheses of an occultation by a cloudy mask at altitude has not been accepted (the landscape in the background would also be obscured).

The disappearances could also correspond to the passage of the UAP behind obstacles (trees, etc.). However, the profusion of electricity and telephone poles and trees of comparable height makes navigation at very low altitudes (and at night) extremely risky, and this assumption is unlikely.

The question of the pink-red light remains open (why would this light have disappeared ?) ; in any event, no testimony mentions the overflight of the airfield at low altitude by a flying object, including crossing the runway twice : if the UAP had radiated in the visible spectrum, at least the control tower personnel would have noticed. In addition, the trajectory is not consistent with the pilot's testimony (sees the UAP north of the airfield just before the IR detection phase).

Control of the flight of a drone at night, very low altitude, over a significant distance is theoretically possible, but technically difficult to perform in the 2013 technologies context, except if we use a recorded waypoints navigation ; in addition, the risk-taking and operational interest of overflight of an inhabited area (discretion ?) and of an airfield in operation do not find a plausible explanation.

In conclusion, the plausibility of this profile, with a little performance drone, is low.

8.3. Constant altitude trajectories:

Depending on the altitude considered, the speed profiles lead to different aerial vehicles hypotheses : "conventional" micro and mini drones are compatible with altitudes of the 600 to 1200 feet range, due to the high speeds required above ; above 1200 feet, speed profiles need to operate fast micro and mini drones.

The analysis of constant altitude trajectories shows that :

- below 1200 feet, no trajectory flies over the sea : the lack of radar detection is not a mandatory,
- whatever the altitude, the final course does not overflies the sea : the hypotheses of impact with the sea cannot be retained.

There is no marked inconsistency regarding the infrared signature of the drone engines. At stable altitude, the disappearance of the UAP image and its splitting are not much compatible with this type of scenario.

The reservations about the consistency with the testimonies are renewed : disappearance without explanation of the pink-red light, no visual testimony other than that of the DHC-8 crew.

No operational scenario can be identified, nor any reason for the lack of notification to the control tower.

The plausibility of the hypotheses is poor.

8.4. Straight and steady speed trajectory (Z1 = 1000 feet, VZ = -2 ft-feet/s)

The trajectory is oriented at 235°, the speeds are less than 50 km/h, the altitude range is between 600 and 1000 feet : the compatible aerial vehicles are the balloons, such as Thai lanterns, and the micro and mini drones (conventional or fast).

The compatibility with the radar detection data is not inconsistent : the low SER (cross-section) of the Thai lantern and the poor radar detection above the ground are enough to explain the lack of detection of the UAP.

The wind data (east wind for 13 to 20 km/h at ground level, east/northeast wind for 19 to 29 km/h in mean level altitude, measured at San-Juan station) are compatible with the calculated UAP performance.

The infrared signature on the video recording looks overly strong when compared to the heat source characteristics of a Thai lantern.

The disappearances and splitting of the infrared image cannot be explained, except if we assume the extinction of the flame of the Thai lantern at its final disappearance.

Impact with sea is not possible.

The analysis of the eyewitness accounts does not formally contradict the hypotheses : the DHC-8 pilot sees the object "in the north" as the aircraft is flying south of the runway ; the tower controllers confirm that. However, there is no explanation for the disappearance of the pink-red light, especially in the Thai lantern hypotheses.

In terms of scenario, skirting the airfield by following a road parallel to the runway is not inconsistent as a drone trajectory , but the reason for this move cannot be explained.

- the drone hypotheses is kinematically and radiometrically consistent, but does not find a reasonable operational justification, except if we compare it with cases of overflight of airports and sensitive areas observed many times in the years 2013-2014,
- finally, the Thai lantern hypotheses is consistent (road, speed), but does not correspond to the radiometric level (the IR signature seems high) ; the slow descent, while combustion is still operating, does not really make sense ; it can only be explained by the existence of a weakly descending atmospheric stream, which is possible given the context of atmospheric instability, but which we cannot confirm.

This trajectory presents a relatively high degree of plausibility for the Thai lantern, average for the drone.

8.5. Trajectories impacting the sea at the apparent impact point (passage flush with the cliff) :

The possible values of the vertical speed on final course, which are constrained by the passage over the cliff, lead to consider speed profiles at the limit of the performance of “conventional” micro and mini drones (in the final phase, the speed is never less than 150 km/h). Only fast micro and mini drones can be considered.

The higher altitude part of the trajectories takes place above the ground, the final part over the sea, but at very low altitude : we will consider that the consistency is correct.

The disappearances of the infrared image in the final course and, even more so the dive, are consistent with these trajectories.

The consistency with the testimonies remains poor : disappearance of the light, no observation of the flight over the airfield has been reported.

In terms of operational consistency, apart from scenarios relating to spy novels (testing mission in the airfield area, we do not see a reasonable explanation justifying these trajectories, except to consider an illicit flight of a drone as it sometimes happens. There have been many cases of this in sensitive areas, including international airports, since 2013.

The table summarizing the plausibility of the assumptions is presented below.

Flight profiles	Flying objects compatible with metric size and speed range	Consistency with radar data	Consistency with wind data	Consistency with object temporary disappearances on vidéo recording	Consistency with the hypothesis of the impact on the sea	Consistency with testimonies	Overall plausibility
UAP accompanies DHC-8 (Z - 100 feet)	Fast mini or microdrones	+	Not applicable	0	0	0	0
Terrain following (H = 100 feet)	Fast mini or microdrones	Undetermined	Not applicable	++	++	+	+
Constant altude flight	Mini or micro drones	++	Not applicable	+	0	+	+
	Fast mini or microdrones	++	Not applicable	+	0	+	+
Staight trajectory at steady speed profile (Z1=1 000 feet, VZ=-2 feet/s)	Thai lantern	Undetermined (SER is small)	++	++	0	+	++
	Mini or micro drones ("conventonal" or fast)	++	Not applicable	0	0	+	+
Constant vertcal speed trajectory impactng the sea at the apparent dive point on video	Fast mini et microdrones	++	Not applicable	++	+++	+	++
Variable vertcal speed trajectory impactng the sea at the apparent dive point on video	Fast mini or microdrones	++	Not applicable	++	+++	+	++

Fig. 30 – Plausibility summary table

9. Conclusions of the study

The study was conducted on the basis of testimonies, radar information, image and digital data embedded on the video images.

The comparison of the radar information with the kinematics of the DHC-8 obtained from the digital data made it possible to check the authenticity and consistency of the testimonies. It also made it possible to dissociate the phenomenon observed on the radar from that observed by the DHC-8 crew and video recorded : the radar echoes which alerted the controllers of the Aguadilla tower are probably due to storm formations drifting to the west, away from the area where the UAP was visually and IR spotted and tracked.

No radar detection corresponds to a potential position of the object observed by the DHC-8.

The image data available is of poor quality, probably from a bad analog copy :

- the size of the UAP could be evaluated : it is of the metric class,
- it was not possible to derive any important information allowing to establish hypotheses as to the nature and shape of the UAP, nor the origin and importance of the heat source at the origin of the IR signature. At most, we can assume that the object appears to be emissive, and has a structure including a hot spot,
- the search for an explanation for the successive disappearances of the UAP image has not made it possible to identify any ascertainable hypotheses (the passage behind trees has been mentioned) ; the hypothetical impact with the sea does not find a realistic explanation with the aerial vehicles that we know, but the ricochet is possible, associated with a misting effect temporarily obscuring the object,
- the splitting of the UAP image could not be explained,
- the image data did not allow to enrich the kinematic analysis.

The use of the digital data embedded in the video made it possible to highlight the impossibility of determine the distance from the DHC-8 to the UAP (indeed, the “target” data designate the ground points behind the cross-hairs).

On the other hand, it was possible to daw the successive lines of sight and to limit on them the segments on which the UAP is located. From there, we were able to build models of potential trajectories that we compared to the testimonies collected, to the information drawn from the images.

Assumptions based on the size of aircraft such as airliners, business jets, fighters (size exceeding the metric dimension) were eliminated.

Among the trajectories, we did not retain :

- the profile in close formation with the DHC-8.

We kept as possible :

- the slow speed profile of an object in slight descent and with a substantially straight trajectory, which may correspond to an object pushed by the wind (Thai lantern ?), but whose thermal signature is poor in view of the images and whose we cannot explain the occultations,
- very low altitude profiles (terrain following) or in slow descent to impact the sea at the point of apparent dive, which could be the result of micro or mini drones propelled by gas nozzle or micro turbine, but whose existence at the time of the facts (2013) is not proven ; however, there is no "reasonable" operational scenario that can be associated with these profiles except that of secret tests (relating to special forces scenarios as in films or novels) or illicit overflight of the airport by drones, many cases of which have been observed in different countries since 2013.