Science Review Board

Delta IV Initiated UFO Reports

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Abstract

A recent Delta IV rocket launch from Cape Canaveral Air Force Station produced a multitude of UFO reports. Those reports centered around one to four orbs following the rocket and a bright blue cloud high in the sky after the passage of the rocket. This paper proposes both of these effects are natural manifestations of the rocket used in this mission.

Delta IV Initiated UFO Reports

Just after sundown on August 7, 2013 the US Air Force successfully launched its sixth Wideband Global SATCOM satellite (WGS-6) from the Space Launch Complex 37 at Cape Canaveral Air Force Station in Florida. The launch vehicle for this mission was a Delta IV Medium-plus rocket. Although rocket launches in Florida are not uncommon, to date this launch has been the direct cause of 15 MUFON UFO reports. Table 1 is a brief summary of what each of these sightings reported.

	County	Mist	Contrail	Rocket	Orbs	Blue Cloud	Video/Image	Additional
1	PalmBeach	**Yes**	no	**Yes**	1	**Yes**	**Yes**/**Yes**	**-**
2	St. Lucie	no	no	**Yes**	4	no	no/no	-
3	Brevard	no	no	**Yes**	4 then 3	no	**Yes**/no	Triangle
4	Palm Beach	**Yes**	no	**Yes**	2	no	**Yes**/no	Aura
5	Palm Beach	no	no	**Yes**	2	no	no/no	Bright Glow
6	Dade	**Yes**	no	**Yes**	1 then 2	**Yes**	no/no	Bow Wave
7	Seminole	no	**Yes**	**Yes**	3	**Yes**	no/**Yes**	Orbs in a Row
8	Broward	no	**Yes**	**Yes**	2	**Yes**	no/**Yes**	Triangle
9	Dade	no	no	no	no	**Yes**	no/**Yes**	Beautiful
10	Dade	no	no	**Yes**	**1**	**Yes**	no/**Yes**	Bright White Cloud
11	Broward	no	**Yes**	**Yes**	2	no	no/no	-
12	Indian River	no	no	**Yes**	4	no	no/no	-
13	Brevard	no	no	**Yes**	4	no	no/no	Diamond
14	Dade	no	no	**Yes**	2	**Yes**	no/no	Bow Wave
15	Marian	no	no	**Yes**	3	no	no/no	-

These sighting reports can be divided into two distinct items being seen. Most of the sightings saw 1 to 4 orbs while some reported a blue (noctilucent) cloud. As is to be expected there are also some sightings where both were seen. This report is designed to discuss the science involved for both effects. In particular hypotheses are provided and defended that both the orbs and noctilucent clouds seen are the natural results of the rocket launch itself.

It is proposed that the orbs was produced by the released glowing remnants of auxiliary strapped on booster rockets and the noctilucent cloud was the result of the expelling of water vapor from the rocket as it traversed the mesosphere. The term hypothesis is used since it is not possible to prove either of these statements. However it will be shown they are reasonable and fit all of the facts of the sightings. Additionally they also cannot be disproven by any fact in any in the sightings. They therefore completely fit the concept of a working hypotheses. As such, they should be continually tested looking for areas of agreement and more importantly areas of disagreement so as to understand the limits of the hypotheses and to make any modifications needed.

1.0 Delta IV Rocket.

An understanding of what was seen can only occur by knowing what was in the sky and how it operates. That is the purpose of this section of the report. Although the relationship between rocketry facts and UFO sightings is not explained in this section the facts the hypotheses are based on italicized and underlined to indicate their importance.

The Delta IV family of rockets is comprised of five configurations: the Delta IV Medium (Delta IV M), three variants of the Delta IV Medium-Plus (Delta IV M+), and the Delta IV Heavy (Delta IV H). These are shown in Figure 1. Each variant uses the same first stage rocket called the Common Booster Core (CBC) The CBC is a liquid propellant rocket that uses cryogenic oxygen (LOX) and Hydrogen (LH2) as its fuel.

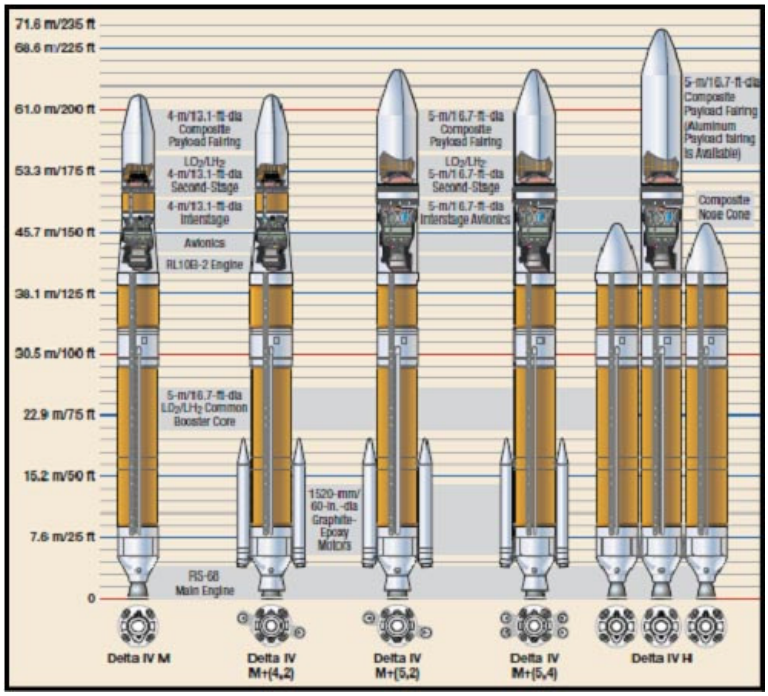

Figure 1: Delta IV Configurations[1]

The initial lifting of the Delta IV M+ is done by the main engine in the Common Booster Core in conjunction with strap-on Solid-fuel Rocket Motors (SRMs). The smaller SRMs burn for just over 1.5 minutes while the CBC burns for approximately 2.4 minutes longer. The first two SRMs are jettisoned at the 100 second mark and the second two (if used) are jettisoned at the 102 second mark[4]. The jettison of the SRMs is accomplished by the use of explosive bolts to disengage them from the CBC. Although it is true the CBC is still under power and will continue to accelerate, if left to nature, the SRMs are only subject to the weak effect of gravity and would basically continue at the speed and direction they had achieved prior to disengaging. They thus could present a risk to the main rocket body and the completion of the mission. To mitigate this possibility ***ordinance thrusters are fired to provide a radial thrust moving the expended SRMs away from the CBC***.

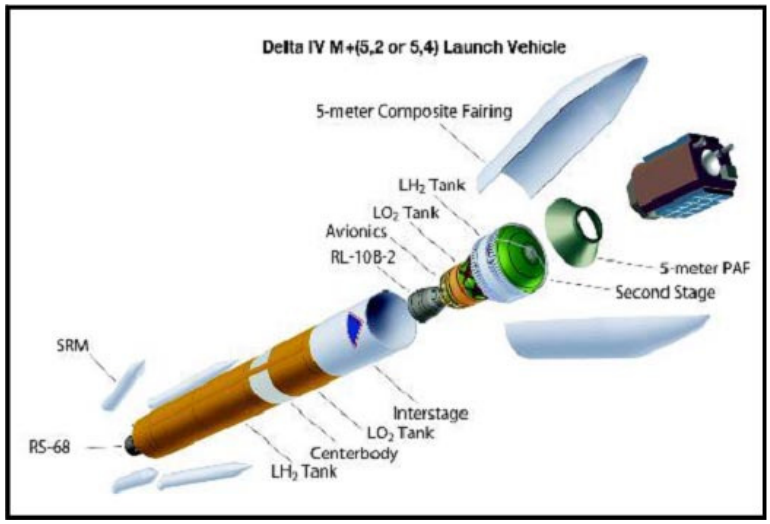

Figure 2: Delta IV M+ - Typical Configuration

Following separation, the Delta IV second stage (seen in Figure 2) takes over and moves the payload to its final location. This engine is approximately 12 meters in length and carries enough ***LOX and LN2 fuel*** to allow for about a 14 minute burn. The payload in the Delta IV rockets is located in a composite bisector fairing which is 11.75 to 19 meters long and 4 or 5 meters in diameter. Once the payload is placed in orbit, the remainder of the rocket moves away into a separate altitude, so as not to provide a threat to the payload.

2.0 Orbs & SRMs

Although the news releases for the Cape Canaveral launch of the Delta IV rocket indicated the rocket was a Medium-plus type, none stated which variant of the type was used. However since the data sheets[2] show that the simpler and less expensive Medium Delta IV can place the a heavier payload[3] into orbit than the Delta IV M+(4, 2), the use of an M+ variant implies it was an M+(5. 4). In addition since it is the writer's contention, and a hypothesis of this document that the orbs that were seen to "follow" the rocket are actually jettisoned SRMs, there has to be more than 2 to accomplish the 3 and 4 orb sightings.

It was stated in the previous section that the ordinance thrusters are fired to provide a radial thrust moving the expended SRMs away from the CBC. The result of this action is to push the SRMs outward from the 4 sides of the rocket. The first 2 SRMs are released 100 seconds into the launch[4]. At that time they are traveling at 1.42 km/sec and are at an altitude of 40.7 km (65.5 miles). The second 2 SRMs are released 2 seconds later. They are traveling at 1.44 km/sec and are at an altitude of 42.3 km (68.1 Miles). Since each pair was traveling with the rocket when they were released, the velocity of the SRMs upon release was also the velocity of the rocket at that time. Therefore the average velocity of the rocket for the 2 second difference is:

$$< v > = (1.42 + 1.44) / 2 = 1.43 \text{ km/sec} .$$

In this 2 second period, the rocket and the second pair of SRMs have traveled:

$$D = 2 \times 1.43 = 2.86 \text{ km} .$$

This allows a determination of the direction the rocket was traveling when it released the first pair of SRMs.

$$\alpha = \sin^{-1} \{ (42.3 – 40.7) / 2.86 \} = 34°.$$

This shows that at this point in its ascent, the rocket was traveling closer to horizontal than vertical. This importance of this angle will be seen when discussing the noctilucent cloud.

While gravity is approximately 98.8% of its value at sea level and therefore has not changed much[5], the frictional effect of air has changed dramatically. In units of 10^{-3}kg/m^3, the density[6] of air at 40 km is approximately 3.996. At seal level it is 12.25 in the same units. It is therefore only

$$100 (03996 / 12.25) = 3.26 \%$$

of its sea level value and would probably not be particularly effective in slowing the first 2 SRMs..

Figure 3: GEM 50 SRM

When discussing the flight of the expelled SRMs some though has to be given to their stability[7]. Rocket stability can be provided in two ways. Stability of the large rockets such as the Delta IV is provided by pivoting the thrust to dampen any unwanted horizontal motion. Stability of smaller items such as arrows is provided by the tail feathers. In the latter case, this is accomplished by keeping the center of pressure[8] (point at which the aerodynamic forces are centered) behind the center of mass. The GEM (Graphite Epoxy Motor) 60 SRM (Figure 3) manufactured by Alliant Techsystems is also vectorable and does not have tail fins[9]. It therefore would not be particularly stable after it expends its fuel.

The following 2 figures are stills derived from the video supplied with case #49616. Figure 4 shows the Delta rocket with 2 orbs to its left and figure 5 taken a little later, shows the rocket with 4 orbs. It is easily seen the rocket has moved

Figure 4: #49646 (earlier) - 2 Orbs

Figure 5: #49646 (later) - 4 Orbs

farther away from the orbs in the second figure. It is also seen that perspective can change the number of orbs seen and the shape of the area enclosed. Unfortunately the witness who took the video did not zoom in close enough to see the orbs before the first two were seen and also missed the generation of the second two by movements of the camera. That lack, however, was corrected by a movie provided with case #50249 (Palm Beach). Although it is difficult to see due to camera movement an orb can be seen to emerge from the rocket near the beginning of the movie. The following is a still made from that movie.

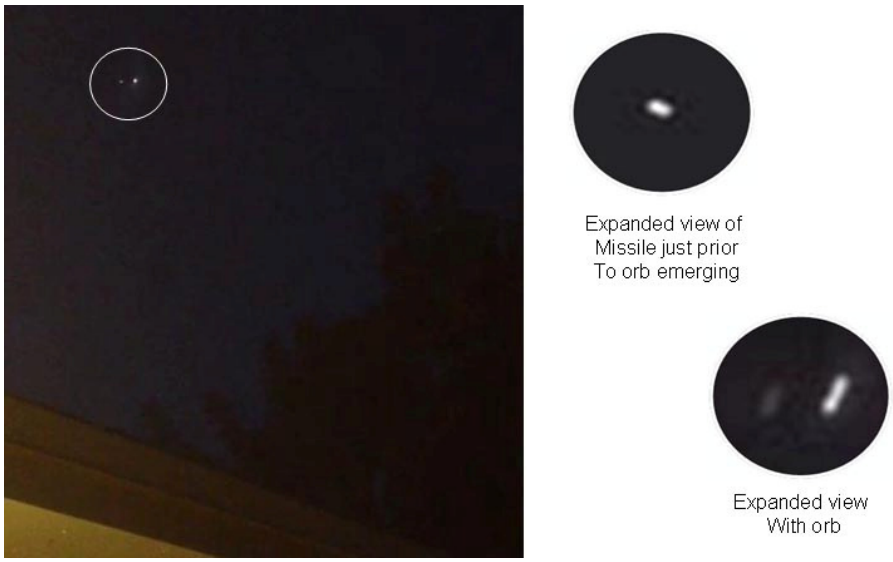

Figure 6: #50249 with expanded views of orb emerging

A final statement should be made at this point, the above is only an indication that the orbs are a manifestation of the released SRMs; it is not proof. It is possible the orb in the picture was initially behind the rocket. The orbs as a manifestation of the released SRMs must remain a hypothesis. As such it could be disproven by a movie of the orbs arriving at the rocket from the outside but it can never be absolutely proven.

3.0 Noctilucent Cloud

There are multiple types of clouds. The most common are Cumulus, Stratus, Cirrus, and Nimbus. Of these types the one at the highest altitude (approximately 6 km) is Cirrus. These clouds are thin and wispy and composed of ice crystals. A much less common type, particularly in Florida, is the night shining or noctilucent cloud[10]. These clouds are also composed of ice crystals but are found in the mesospheric atmospheric layer at approximately 75 to 85 km. Noctilucent clouds are normally too faint to be seen, and are visible only when illuminated by sunlight from below the horizon while the lower layers of the atmosphere are in the shadow of the Earth. Figure 7 is a photograph of a standard noctilucent cloud over Scotland.

Figure 7: Noctilucent Cloud over Scotland

It can be seen that in its natural state, the cloud is thin and somewhat ragged, but also is seen to exist over a relatively large portion of the northern sky.

Figure 8: Noctilucent Cloud seen in Dade County Florida

Since the mesosphere contains very little moisture and is extremely thin, the ice crystals can only form at temperatures below about −184 °F. That is the reason these clouds are rarely seen at latitudes less than about 40 degrees (New York City) such as Florida. However, the existence of Cape Canaveral and liquid propellant rocketry has modified this last statement. Figure 8 was submitted to MUFON in case #49594. As is obvious, the difference between

figures 6 and 7 is the extent of the cloud. The cloud in Figure 7 arises from water vapor that exists throughout the northern polar regions while the cloud in figure 8 exists due to a local concentration of water vapor.

As stated in section 1, the Delta IV uses cryogenic liquid oxygen (LOX) and liquid hydrogen (LN2) as its fuel. When hydrogen is burned it combines with the oxygen to produce a large amount of energy. Additionally, as a byproduct, it produces water vapor which is expelled with the energy out of the rocket's nozzle. That exhaust is the source of the local concentration of water vapor in Figure 8 and therefore also the noctilucent cloud shown in figures 9, and 10.

The question that should arise at this point is; why do the pictures show a cloud and not a contrail? The answer is related to that 34 degree angle calculated in section 2. That angle was referred to the ~40 km altitude at which the SRMs were released. Since the payload is to be placed into orbit the rocket does follow a simple vertical path, it spirals out from the ground. In the mesosphere (75 – 85 km), it will be at an angle even less acute than its value determined at 40 km. The rocket is therefore heading away from its observers in Florida and they are basically seeing the contrail end on.

Figure 9; Case #49595 – Ft. Lauderdale, Broward

Figure 10: Case #49606 – Winter Springs, Seminole

There is an interesting item that can also be seen in figure 9. Slightly to the right and lower, a faint image (S shaped) of the exhaust of the rocket at lower altitudes can be seen. In this case, that is actually a vapor or standard cloud rather than the ice crystal (noctilucent) ones being discussed in this document.

It is to be admitted that the writer was initially tempted to consider the noctilucent clouds being seen a result of the expelling of left over propellant from the stage 1 rocket. It is known from past experience that leaving debris in space with small amounts of propellant in them poses many risks. A leak in a propellant wall can cause an unwanted thrust from the expelled gas and threaten other objects. It is also known that the primary source of space debris is accidental explosions[11] in spent orbital vehicles. To mitigate those risks, operators are now required to expel of all leftover fuel[12] prior to leaving the object in orbit. The problem determined with assuming that as the cause of the clouds is that the separation of stages 1 and 2 occurs at approximately 185 km. That altitude is well into the thermosphere which is above the mesosphere and its temperature is much too hot to allow the existence of ice crystals.

4.0 Conclusions

As stated in the beginning of this document, the Delta IV launch from Cape Canaveral the evening of 7 August resulted in 15 sightings being reported to MUFON. Although this document hasn't proven that the source of the sightings

is the Delta IV rocket, enough evidence has been provided that strongly implies it. The arguments for making that determination are listed below. As of this point, the only argument against the source being the Delta IV rocket, is that it hasn't been absolutely proven.

Orbs following the Rocket:

1. The maximum number of orbs never exceeded the number of SRMs released.
2. The video provided with case #50249 seems to show an orb emerging from the rocket.
3. As a result of the main rocket engine running while the SRMs are radiating away their stored heat energy from a prior burn period, the rocket is much brighter than the orbs in all sightings.
4. Since the SRMs are released pair-wise 2 second apart, there is a small difference in location for the 2 pairs adding to the skewing of any pattern they could form.
5. Since SRM stability is normally achieved via vectorability built into the nozzles and that has no effect when the engine is not running, the side-ward motion produced by the ordinance thrusters cannot be compensated for and can cause a tumbling motion which would cause am oscillating or blinking effect. Multiple sources reported the orbs to be blinking.
6. Since the ordinance thrusters for the first two SRMs and those for the second two fire at different times and since the empty SRM shells can not have exactly the same weight or center of mass, the blinking effect would of necessity be random. Multiple sources reported the blinking to be random.
7. No observer has reported seeing the orbs arrive at the rocket from any other location but a film (Appendix B) shows them being created at the rocket..
8. The orbs seem to eventually randomly disappear rather than fly off to some other location as a group.

Noctilucent Cloud: The basic ingredients for the formation of a noctilucent cloud are temperatures from minus 225 to minus 190 degrees Fahrenheit, water vapor, and dust particles to serve as seeds for the ice crystals that form the clouds.

1. The temperature in the mesospheric layer of the atmosphere is too high for the formation of a Noctilucent Clouds at latitudes as low as Florida. Noctilucent Clouds therefore do not naturally form at these latitudes.
2. In areas where they are not common, noctilucent clouds are quite impressive. If they had occurred at any other time they would have been noticed. No other reports of these clouds in Florida have been found.
3. In any particular region the water vapor density and dust in the mesosphere layer is relatively homogeneous. Therefore naturally occurring noctilucent clouds tend to be large in extent. The clouds seen in these sightings are all very localized and small. Ergo their source had to be a localized volume of water vapor.
4. The fuel used in the Delta IV rocket is cryogenic Oxygen (LOX) and Hydrogen (LN2). The byproduct of this combustion is water vapor which is expelled with the energy through the nozzle. The passage of the rocket therefore leaves a localized trail of water vapor.
5. The mesospheric layer of the atmospheric layer of the atmosphere only exists between ~75 km and ~85 km. The rocket spends approximately 18 seconds in this layer[13] traveling upward and horizontally. From the ground this cloud seen would be seen as more cloud like then contrail like.
6. The timing of the Delta IV launch was perfect to display a noctilucent cloud. The sun had set at 8:08 pm EDT and twilight would end at 8:33 pm, The launch occurred just prior to the end of twilight at 8:29 pm Using the same source and calculations as item 5, the rocket was in the mesospheric layer from ~8:31 and 16 seconds to ~8:31 and 34 seconds.

Due to the above points the only reasonable conclusion to draw is that both of these effects were caused by the Delta IV rocket. At this time any other conclusion would constitute a conclusion based on faith (a religious belief) rather than a scientific one.

Notes and References

1. For rocket configuration names such as "M+(x, y)": the first number (x) denotes the second stage diameter in meters and the second number (y) denotes the number of strapped-on Solid Rocket Motors (SRMs).
2. United Launch Alliance; Delta IV: Payload Planners Guide 2007: Figure 2-5; page 2-6:
3. Although the M+(5, 2) carries more fuel than the M+(4, 2), due to its additional weight (~10 metric tons) its maximum payload weight is significantly less (> 13%) than the M+(4, 2). The advantage the M+(5, 2) has is its larger fairing (diameter and length) which would allow a larger size payload.; "Space Launch Report: Delta IV Data Sheet"; http://www.spacelaunchreport.com/delta4/html:
4. United Launch Alliance; Delta IV: Payload Planners Guide 2007: Figure 2-5; page 2-6: For a launch of an M+(5,4) Delta rocket, the first 2 SRMs are jettisoned 100 seconds into the launch. At that time they are traveling at 1.42 km/sec and are at an altitude of 40.7 km. The second 2 SRMs are jettisoned 2 seconds later. They are traveling at 1.44 km/sec and are at an altitude of 32.3 km.
5. Handbook of Chemistry and Physics: W.M. Haynes editor: 92nd Edition; 2011; Sect. 14 "Geo-Astro"; pg 10; The radius of the Earth is approximately 6731.0 km.; CRC Press: ISBN 978-1-4398-5511-9

   Since gravity is proportional to the inverse distance between the object and the center of the Earth, the weight of any object at an altitude of 40.7 km is approximately 98.8% of its weight at sea level.
6. ibid: Sect. 14 "Geo-Astro"; pg 11
7. NASA Rocket Stability Condition: http://exploration.grc.nasa.gov/education/rocket/rktstabc.html
8. NASA Determining the Center of Pressure: http://exploration.grc.nasa.gov/education/rocket/rktcp.html
9. ATK Space Propulsion Products Catalog: Release OSR No. 12-S-1902; 7 Aug. 2012; Pg 43
10. Encyclopedia of Science and Technology; 5th edition; 2005; pg 1360: McGraw Hill: ISBN 0-07-142957-3
11. NASA Orbital Debris Program Office: "Technical Report on Space Debris"; UN_Report_on_Space_ Debris99.pdf, pg 25, Paragraph 76, item b.
12. NAS Orbital Debris Program Office: "U.S. Government Orbital Debris Mitigation Standard Practices"; USG_OD_Standard_Practices.pdf, Mitigation Standard Practices, pg 1, item 2.2.
13. United Launch Alliance; Delta IV User's Guide 2013: Figure 2-5, Section 2.2.2; Page 2.6: The figure lists the altitude as 42.3 km at 102 seconds and 126.2 km at 204 seconds. By linear interpolation it can be found the rocket is at the 75 km altitude at approximately 136 second and at the 85 km altitude at approximately 154 seconds. The rocket therefore spends approximately 18 seconds in the mesospheric layer.
14. M Gadsden, P Parviainen; "Observing Noctilucent Clouds"; International Assoc. of Geomagnetism & Astronomy; Sect 2, VISUAL OBSERVATIONS; Sub-Section 2.5, Systematic Observation; Paragraph, Colour; Pg 13: 2006: ISBN 0-9650686-0-9: Noctilucent clouds are typically a pearly white or electric blue. When observed, the blue color is due sunlight passing through atmospheric ozone regions at an oblique angle, thus resulting in selective absorption in the yellow frequency band.

APPENDIX A

WGS-5 Launch: 24 May 2013

The WGS-5 launch from Cape Canaveral occurred at 8:27 EDT on 24 May 2013. As with the later launch on 7 August 2013, this launch was a Delta IV M+(5. 4) rocket. Since on 24 May, sundown occurred at 8:11 EDT and twilight ended at 8:37 EDT this launch was very close to being a replica of the 7 August launch. The only difference was in relation to the sun where this launch was 6 minutes earlier. The night sky was therefore not quite as dark and the clouds seen were more white than blue. (The cause of the color difference will be discussed below.) This launch was the direct cause of 7 MUFON UFO reports. Those reports are summarized in the following table.

	County	Mufon #	Time	Contrail	Rocket	Orbs	Cloud	Additional
1	Osceola	48008	8:50	Yes	Yes	3	no	Orbs came from rocket
2	Dade	47863	8:32	no	no	no	Yes	Rotating Self Luminous cloud
3	Broward	47637	8:00	no	no	no	no	Glowing
4	Pinellas	47627	8:27	no	Yes	4	no	-
5	Duval	47622	8:30	Yes	Yes	no	no	Spiral Smoke /Teardrop cloud
6	Orange	47619	8:31	no	no	no	Yes	-
7	Broward	47617	8:00	no	Yes	no	Yes	-

As stated most of these reports stated the noctilucent cloud was white instead of blue. Examples of these clouds are seen in Figures A1 and A2 below.

Figure A1: 47617 file 1

Figure A2: 47619: file 4

The color difference is easily seen when comparing these clouds to those in the main document (figures 9 and 10). To explain the reason for this difference one has to first understand why the clouds in the main document were blue. That blue coloring[14] was a result of the sunlight that was illuminating the clouds, first passing through a layer of ozone which selectively absorbed light in the yellow frequency range. Since the ozone layers are located below the mesosphere, the sun has to be low enough below the horizon so as to first traverse to lower ozone levels before encountering the clouds in the mesosphere. This illustrated in Figure A3.

Since this launch occurred 6 minutes earlier (in relation to the end of twilight) than the August launch, the sun in these sightings had not yet gone down enough to first go through those ozone layers. That 6 minute delta also provides enough time for the clouds to dissipate prior to the color turning blue.

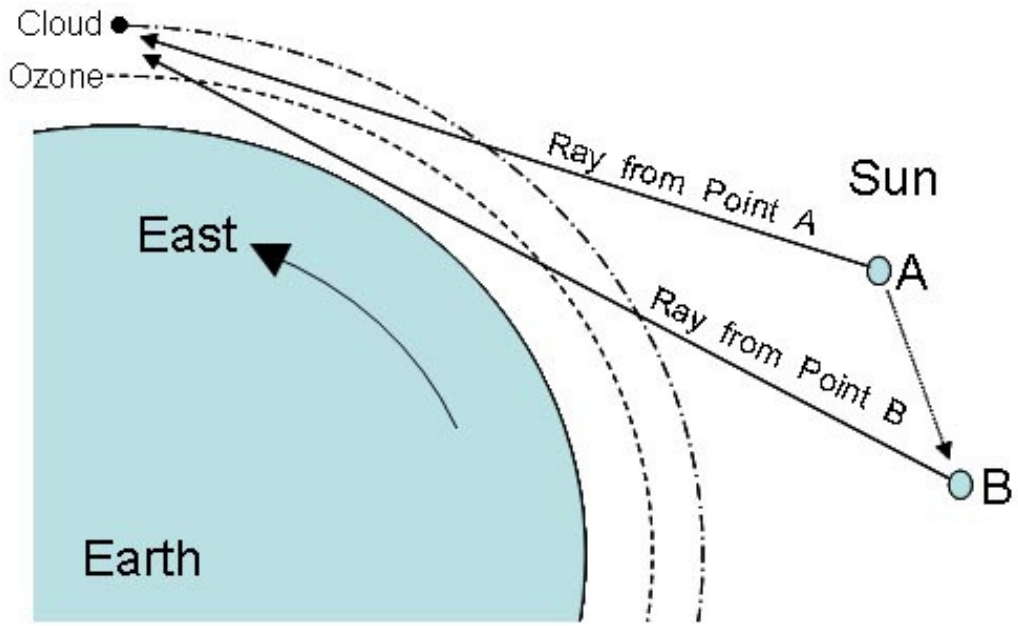

Figure A3: Noctilucent Cloud Color

In Figure A3 the early twilight period is denoted by location A for the sun while the late twilight period is denoted by location B. As can be seen the rays from the sun to the cloud from location A do not traverse the Ozone layers while the rays from location B do. Since it is the ozone layer that gives these clouds their blue coloring, later sightings will see a bright blue cloud while earlier sightings will see a bright white cloud. As is to be expected, the darker the night, the easier it is to see noctilucent clouds. Therefore most sightings report a bright blue cloud.

APPENDIX B

WGS-4 Launch: 20 Jan 2012

The WGS-4 launch occurred at 7:30 pm est from Cape Canaveral. On the 20th, the sun set at 5:52 pm est and twilight ended at 6:17 pm est. Therefore there could be no noctilucent cloud sightings for this launch. While there could have been sightings of orbs from the release of the SRMs none were reported to MUFON. There were only 4 reports for this date in Florida and none were near the time of the launch.

There was, however an interesting video of this launch found at http://www.spaceflight101.com/wgs4-updates.htm showing the entire initial portion of the launch. In particular it shows the shutdown of the SRMs and their release along with a running account of the mission and the time. The orbs can clearly be seen being created at the rocket and their creation coincides exactly with the narrative Additionally, the blinking of the separated SRMs is clearly seen. The identification of the orbs with the SRMs is thus clearly demonstrated. The following 2 figures are derived from that video.

Figure B1: Separation of 1st 2 SRMs

Figure B2: Separation of 2nd 2 SRMs

APPENDIX C

WGS-3 Launch: 5 Dec 2009

The WGS-3 launch from Cape Canaveral on 5 Dec 2009 was the first launch that used the Delta IV M+ rocket. Prior launches had used the Atlas V rocket. Since the Atlas V uses a different fuel and would require an entirely new descriptive section, the earlier launches are not contained in this document The WGS-3 launch occurred at 8:47 pm EST from Cape Canaveral. On the 5th, the sun set at 5:26 pm EST and twilight ended at 5:52 pm EST. Therefore there could be no noctilucent cloud sightings caused by this launch.

There were 2 MUFON reports from Florida for this date. While report #20952 is clearly not related to the launch, the same is not true for report #20886. That report stated that at 8:55 pm a witness in Jacksonville saw a fireball in the eastern sky. Since the fireball seemed to be traveling horizontally rather than upwards, the witness dismissed the possibility of it being a rocket. However, after the first few minutes of these launches, most rockets would be seen to be traveling more horizontally than vertically It is the belief of this writer that this sighting should have been labeled as an IFO related to the Delta IV launch of WGS-3. It is believed it was missed because the launch was under the auspices of the USAF rather than NASA