The Truth about the "Endor Holocaust"

by Gary M. Sarli

Introduction

At the Star Wars Technical Commentaries website, author Curtis Saxton makes the claim that because of the size of the Second Death Star (DS2) and its distance to Endor, the destruction of the DS2 would have devastated Endor and caused mass extinctions. He calls this theory the "Endor Holocaust", and he claims that it is the direct result of canonical evidence as seen on film in *Return of the Jedi*. As I will show in this detailed rebuttal, his conclusions are not supported by the canonical evidence. The "Endor Holocaust" could not have happened.

Revision History:

May 31, 2004: First publication.

June 9, 2004: Corrected size of shuttle to match movie blueprints. Changed orbit of DS2 to account for cockpit views from *Tyderium* and reverse-angle view of Vader's shuttle on approach to DS2. Added "Implosion" section to explain the deceleration of Death Star's debris in seconds after explosion. Provides support for wormhole described in *The Glove of Darth Vader* (1992) and referenced in "Endor and the Moddell Sector" (*Star Wars Gamer* #9, 2002) and *Star Wars Insider* #76 (2003). Expanded Appendix to explain different uses for trigonometric analysis of photographs, particularly extrapolating angular widths of objects that are partially off-screen and calculating the distance to spherical objects.

August 10, 2004: Introduced new and higher-quality screen shots to gather more accurate data. Added sections on continuity and standards of evidence. Added expected margin of error (±2 pixels and/or ±0.5°) for all direct measurements, creating a consistent standard for accepting or rejecting official material.

Special Thanks:

- Curtis Saxton, for putting so much effort into such an interesting puzzle.
- R.S. Anderson, for suggesting some illustrations and providing highly useful images and feedback.
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- "Darth-Wong," for pointing out the cockpit interior images of *Tyderium* and the reverse-angle shot of Vader's shuttle on approach that made the original calculated orbit (from the "Falcon Approaching" shot) impossible.
- Everyone who posted comments on this article on the various Star Wars message boards, for applying a critical eye and providing invaluable feedback.

… and, of course …

- George Lucas, for coming up with this universe in the first place.

Comments and Feedback

All discussion on this article should be posted here. The author may be contacted here.

Continuity

Before going into a detailed analysis, it is important to establish the parameters of this discussion. Saxton discusses this subject in great detail in Continuity, Canon, and Apocrypha: "The *STAR WARS* films are the only primary reference. With the exception of only a few minor points, they are indisputable. This is not a merely personal opinion; it is the explicit policy of the Continuity and Production Editors at Lucasfilm.... Therefore the films and their adaptations are **canon**, meaning that they take precedence in essentially all matters. Any other form of unfilmed *STAR WARS* fiction may be **official**, meaning that it is subordinate to canon and is required to be consistent with other official works." This is the fundamental standard for all discussion of Star Wars continuity, and I adhere to it within this article.

What do you do in the event of a dispute between canon and official material? Saxton addresses this as well: "**Only reject existing material where absolutely necessary.** Story elements must have genuine continuity problems to justify discarding them; material shan't be thrown away simply because many people hold it to be repugnant or embarassing [*sic*]. The *STAR WARS Holiday Special* is a prime example. If a source is uncomfortable or incongruent at face value, it is often possible to add background circumstances to alter its significance and give a more realistic perspective." [emphasis added] Of course, this does leave the definition of

"absolutely necessary" open to interpretation; I address this issue and attempt to establish a **standard of rejection** in the following section.

Standard of Rejection

At what point is it "absolutely necessary" to reject official material? In the case of *descriptive material* (e.g., "How big is a star destroyer?"), the following standard is used:

- If the official descriptive material does not fall within the **expected margin of error** for data collected from canonical sources, the official descriptive material is rejected; if not, then,
- If the official descriptive material is contradicted by *newer* official descriptive material (at least 2 years more recent, to account for the time lag between concept, writing, editing, and publication; however, errata, second printings, and so forth are always considered "newer"), the older official descriptive material is rejected; if not, then,
- If the official descriptive material is contradicted by a *majority* of official descriptive material, the minority official descriptive material is rejected; if not, then,
- If the official descriptive material is contradicted by *higher-ranking* official descriptive material, using the following ranking –
    1. Film novelizations and radio dramas;
    2. Materials set during the time frame spanned by the original trilogy (Episodes IV – VI) or the prequel trilogy (Episodes I – III);
    3. Materials set in the time frame *between* the prequel trilogy and the original trilogy (i.e., after Episode III but before Episode IV);
    4. Materials set before the prequel trilogy or after the original trilogy (i.e., before Episode I or after Episode VI);

  – the lower-ranking official descriptive material is rejected; if not, then,
- The official descriptive material is accepted.

The **expected margin of error** is defined using the following assumptions: 1) All dimensional measurements of screen shots are expected to be accurate within ± 2 pixels (i.e., each end of an object is probably over- or underestimated by no more than 1 pixel), and 2) all angular measurements of screen shots are expected to be accurate within ± 0.5°. Given this, the minimum and maximum values for each measurement are calculated. If an official measurement falls within this range, it is *accepted*; however, if an official measurement falls outside this range, it is *rejected*. In the case of quantitative analysis (i.e., statistics), the scientific standard of a 95% confidence interval is used. If an official measurement falls within this 95% confidence interval, it is accepted; otherwise, it is rejected.

In the case of *conceptual material* (e.g., "How does a lightsaber work?"), the following standard is used:

- If the official conceptual material is *specifically* contradicted by canon, the official descriptive material is rejected; if not then,
- If the official conceptual material is contradicted by *newer* official conceptual material (at least 2 years more recent, to account for the time lag between concept, writing, editing, and publication; however, errata, second printings, and so forth are always considered "newer"), the older official conceptual material is rejected; if not, then,
- If the official conceptual material is contradicted by a *majority* of official conceptual material, the minority official conceptual material is rejected; if not, then,
- If the official conceptual material is contradicted by more parsimonious (i.e., less complicated and/or requiring fewer assumptions) official conceptual material, the less parsimonious official conceptual material is rejected; if not, then,
- If the official conceptual material is contradicted by *higher-ranking* official conceptual material, using the following ranking –
    - Film novelizations and radio dramas;
    - Materials set during the time frame spanned by the original trilogy (Episodes IV – VI) or the prequel trilogy (Episodes I – III);
    - Materials set in the time frame *between* the prequel trilogy and the original trilogy (i.e., after Episode III but before Episode IV);
    - Materials set before the prequel trilogy or after the original trilogy (i.e., before Episode I or after Episode VI);

  – the lower-ranking official conceptual material is rejected; if not, then,
- The official conceptual material is accepted.

In the case of rejected official conceptual material, it is often possible to explain apparent contradictions. For example, *The Phantom Menace* established that there are only two Sith at any one time, but *Tales of the Jedi* comics (set thousands of years before the movies) contradict this. The explanation of this is that there were two different groups known as the Sith, with the older being an actual civilization (and, later, an empire), while the newer is more like a cult of renegade Jedi, inspired by ancient Sith lore. (This, in turn, became the official

explanation in later publications such as the *Dark Side Sourcebook*; for additional examples, see Saxton's Continuity, Canon, and Apocrypha). When explaining such a contradiction in this manner, the argument is evaluated in terms of its parsimony; if a given explanation stretches the bounds of possibility *too* far, it must be rejected. Ultimately, however, this is a matter of subjective evaluation unless and until official material appears to explain the contradiction.

Given these rules, I can consistently determine whether any given official material should be rejected or accepted. If official material is accepted, it will be treated as true and correct for all purposes throughout the remainder of the article. For example, if analysis of canonical evidence yielded a calculated length of 6.2 meters for a TIE fighter, and the expected margin of error was 5.9 – 6.7 meters, then the official length of a TIE fighter (6.3 meters) would be accepted because it is within the margin of error; therefore, if I had further calculations using the size of a TIE fighter, I would use the official 6.3-meter length. This is the methodology used throughout this article.

After the Battle of Endor

Canonical and Official Sources

What is the fate of Endor according to canonical and official sources? The following is a brief list of the available information – sources are listed in the order of precedence, starting with canon and then showing official sources starting with the most recent:

***Return of the Jedi*:** The film itself only shows the immediate aftermath of the Battle of Endor. There is clearly enough time between the destruction of the Death Star and the celebration at Bright Tree Village (the Ewok settlement shown in the film) that word of the Emperor's death had spread all the way to Coruscant, Bespin, and Tatooine, so there was at least a gap of an hour or two, and quite possibly considerably more. Furthermore, it is daytime during the battle on the surface of Endor (judging from visible shadows, it was probably no later than late afternoon at the end of the battle), but during the celebration it is nighttime – stars are visible in the sky while Rebel fighters are launching fireworks. Therefore, we can conclude that no catastrophic damage was inflicted anywhere near Bright Tree Village in the few hours after the DS2's destruction. [Note: This does not rule out the possibility of an irreversible ecological disaster whose effects would not be visible for several hours, days, or weeks.] This source does provide the only on-screen evidence for the size and proximity of the DS2; this allows some calculation of what, if any, debris would have hit Endor after the DS2's destruction – this will be the subject of the majority of this article.

***Star Wars Insider* #76:** The question of the Endor Holocaust was directly addressed in a Q&A column by Pablo Hidalgo. The complete text is reproduced below:

> **Q:** I read somewhere that Endor suffers an immense cataclysm after the destruction of the Death Star, and all the Ewoks are killed. Is this true?
>
> **A:** Don't buy into anti-Ewok propaganda. It sounds like the Empire's behind that particular rumor.
>
> Though many learned scholars and students of physics have micro-examined the Star Wars films for scientific accuracy and have come away with an entertaining degree of consistency, in some cases, science has to be thrown out the window. Armchair physicists have to look away when a screaming TIE fighter passes through the vacuum of space, when a particularly volatile explosion combusts in an airless void, or when giant yellow letters inexplicable to the known rules of the universe float lazily into infinity. Not to put too fine a point on it, but it's only a movie.
>
> And it's a movie with a happy ending. Though there are undoubtedly any number of physical models that would indicate that the detonation of a moon-sized object in the upper atmosphere of a forest planetoid would wreak untold havoc on the local ecology, that's not what happens. It was George Lucas' intent that the fuzzy little Ewoks and their Rebel friends lived happily ever after, and nuclear winters don't fit into his model.
>
> But there is a pseudorational explanation -- from an unlikely source: *In* The Glove of Darth Vader*, a children's book published in the early 1990s, is a description of a wormhole that opened up during the Death Star's fiery demise and sucked debris -- including Darth Vader's indestructible glove (yeah, you read that correctly) -- all the way across the galaxy to the planet Mon Calamari.*
>
> *If we accept the hazy rules of hypermatter quasi-physics and plot-convenient wormhole, then surely suggesting that the worst of the Death Star fallout also got sucked out into hyperspace isn't too much of a stretch.* [emphasis added]

"Endor and the Moddell Sector," *Star Wars Gamer* #10: This article, the most comprehensive single source on Endor, its star system, and the other systems in the sector, directly addresses the fate of Endor after the DS2's destruction:

> The explosion of the second Death Star filled the Forest Moon's orbit with thousands of tons of debris, ranging from pebble-sized bits to 100-meter sections of the space station. *While a few chunks fell onto the Forest Moon, the satellite was spared any significant environmental damage.* [35, emphasis added]

Furthermore, it describes a black hole near the Endor system:

> The Endor Gate is a black hole located several light years off the hyperspace route between Endor and Sanyassa. Since it isn't especially large and is well-charted, it shouldn't pose a danger to a competent starship captain. However, spacer's tales tell of strange things happening on the space lanes near the Endor Gate – most notably *ships found drifting whose captains swear they were traveling on the other side of the galaxy before their systems went dead*. Cynics note that for all the outlandish tales, none account for any independent ships weeks late on a run. [36-37, emphasis added]

The sidebar at the end of this article includes the following note on sources:

> *The Glove of Darth Vader*, Paul and Hollace Davids, Bantam Skylark 1992. How did the glove of Darth Vader wind up on Mon Calamari? Musings on the nature of hyperspatial anomalies provided the background for the Endor Gate in this article. [41]

This book is discussed later in this section.

***X-Wing: Wedge's Gamble*:** While touring the Galactic Museum on Coruscant, Wedge Antilles and members of Rogue Squadron encounter some stuffed Ewok specimens. They are described as having been made extinct on their native world through the actions of the Rebel Alliance. [Note: This is the only secondary evidence that could be interpreted as supporting the Endor Holocaust; however, it can just as easily be interpreted as Imperial propaganda.]

***The Truce at Bakura*:** The Rebels are shown staying at Endor for at least the next day after the battle and destruction of the DS2. At this point, there is still no significant observable environmental damage.

***Dark Apprentice*:** Kyp Durron visits the location of Darth Vader's funeral pyre approximately seven years after the Battle of Endor. Trees, forest, twigs and dead leaves, underbrush, one live Gorax, and a handful of live Ewoks huddles in their homes are described, but no mention of environmental disaster is made. [Source: Saxton; Note: Saxton notes that the trees and forest are never specifically described as being alive, and he also hypothesizes that Durron's recent turn to the dark side may have been clouding his perceptions.]

***The Glove of Darth Vader*:** As described above, the glove of Darth Vader was discovered in some debris of the DS2 in the oceans of Mon Calamari. It is theorized within the book that a wormhole was somehow created during the explosion of the DS2, drawing debris across the galaxy to the Mon Calamari system – the debris containing Darth Vader's glove ended up on a trajectory that led it to enter the Mon Calamari atmosphere and land in the ocean. [Note: Although it sounds far-fetched, the survival of significant chunks of debris through reentry and surface impact is quite plausible given the real-world debris observed from Skylab, Mir, and the *Columbia* tragedy.]

***Dark Force Rising*:** Leia travels to orbit around Endor, but does not visit the surface. Endor is perceived to be "lush" and "green" – no mention is made of any ecological disaster, past or present. [Note: Saxton suggests that the green color could be interpreted as algae or lichens that have survived after the disaster.]

***Star Wars* (Marvel Comics Series):** Late in the series (c.1984-1985), the Rebels are shown using Endor as a base of operations for some time after the DS2's destruction. Again, no evidence of any environmental disaster is shown.

Thus, we see that 1) the *canon* does not show any environmental effects for at least the few hours after the battle, 2) George Lucas' *intent* for the Ewoks is specifically described as living "happily ever after," 3) Endor is specifically described as suffering no "significant environmental damage," 4) a wormhole is described that pulled at least some (or, as *Insider* suggests, most) of the debris to the other side of the Galaxy, providing an explanation of Endor's survival, 5) the few times that post-DS2 Endor is directly shown, no evidence to the contrary appears, and 6) the only evidence that could be interpreted as being in opposition to #1-#5 does not actually show Endor itself and therefore appears to be Imperial propaganda.

Saxton argues that this is all contradicted by the canon itself – clearly, however, the burden of proof is on him because of the wide variety of official material that specifically and indirectly contradicts his position. His argument is outlined below, and readers are encouraged to read his article in its entirety.

Outline of "Endor Holocaust" Theory

How, exactly, does Saxton reach the conclusion that the destruction of the DS2 spelled certain doom for the Ewoks?

1. He calculates the size of the DS2, using these sources as evidence:
    a. The size of the equatorial trench
    b. Concept art (*not canonical*)
    c. Interviews (*not canonical*)
    d. Matte paintings (*only canonical if a given portion appears on film*)
    e. "Astrophysical considerations," specifically the minimum size of Endor and the relative size of the DS2
    f. Conclusion: DS2 is between 800 km and 920 km in diameter.

2. He estimates the minimum size of Endor, given what is known about planets, moons, and the necessary preconditions for Endor to support Earth-like gravity and a breathable atmosphere.
    a. Ewok gliders appear not to have enough lift to operate under Earth's normal gravity (1g).
    b. Endor therefore has slightly less than 1g gravity, around 0.8g.
    c. Anything less would start to be visually apparent (e.g., things would fall slower, people would hop instead of running, etc.)
    d. Endor has a planetary density approximately equal to Earth's (5.5 g/cm^3). (*assumption*)
    e. Conclusion: Endor's radius is no less than 5,200 km (diameter = 10,400 km).
3. He calculates the distance between the DS2 and Endor, using the following evidence:
    a. Screen shot from the bridge of *Home One* shortly after exiting hyperspace, showing entire profile of both DS2 and Endor.
    b. Screen shots of holographic tactical display onboard *Home One*.
    c. Other screen shots showing DS2 over Endor. (Note: No specific image is referenced here.)
    d. Conclusion: DS2 is only 2,000 km above the surface of Endor.
4. Given this, he estimates the environmental impact of the DS2 explosion:
    a. Given the apparent speed of the explosion (i.e., well in excess of escape velocity), all fragments not propelled directly toward Endor will not endanger the planet.
    b. Given the size and distance of Endor, 15.4% of DS2's mass will hit the surface.
        i. "At least thirty" large chunks (i.e., "multi-kilometre" in size) are visible after explosion – these are large enough to cause extinction-level events (e.g., the asteroid that killed the dinosaurs)
        ii. The remainder of the mass is vaporized, entering the atmosphere as "soot"
            1. That much mass would create a layer "a few dozen meters" deep over the entire planet, so even if the large impacts are avoided, the planet is doomed.
    c. The possibility of an "implosion," suggested by some readers and presumably required for any wormhole, is dismissed as not being empirically supported (i.e., Saxton finds no canonical evidence suggesting that such an event could have taken place) – he does not show his specific calculations or evidence, however. Saxton concludes no mitigating factors could have saved Endor from environmental catastrophe and mass extinctions.
5. Saxton's conclusion: "The mass-extinction event at Endor is an inevitable physical consequence of the circumstances at the end of *Return of the Jedi*. As such, it indirectly enjoys **canonical status**, even though it was not clearly portrayed in the film." [bold emphasis added] He further adds: "Avoiding the Endor Holocaust is completely impossible. It is an inevitable consequence of observable facts of the *Return of the Jedi* film. Endor is a depopulated wasteland."

Saxton's argument is primarily dependent on the following two calculations: 1) The size of the DS2, which itself can be used to calculate its proximity to Endor and the amount of debris that would strike Endor, and 2) the characteristics of the DS2 explosion, including the velocity of its debris and any potential acceleration or deceleration. If the first is incorrect, the amount of debris striking or landing on Endor may be considerably smaller, thereby reducing the magnitude of any environmental impact. If the second is incorrect, the amount of debris escaping a possible implosion may also be considerably smaller. In the following section, I will address this first issue and attempt to verify his calculated size of 900 km and orbit of 2,000 km altitude for the DS2.

Saxton's Size and Orbit for the Second Death Star

In Appendix 1, Appendix 2, and Appendix 3, I outline my methodology for calculating the size and distance of objects given a photographic image. In brief, a screen shot can be analyzed to determine the angular width of a given object; this, in turn, allows the size or distance of an object to be calculated. (If you know *either* the size or distance, you can calculate the other value; if you have *neither* the size nor distance, you can still calculate the proportion of size to distance.) Using this methodology, I will compare Saxton's calculated diameter of 900 km and orbit of 2,000 km altitude to screen shots from the movie. In all cases (and throughout the entire article), I accept Saxton's size of 5,200 km radius (10,400 km diameter) for Endor. Distances are measured to the *center* of the DS2 and Endor unless stated otherwise.

"Death Star Over Endor" (Source: Saxton)

Calculated Distance to Endor (86.12°): 7,616.1 km
Calculated Distance to DS2 (21.71°): 2,389.5 km (using 900 km diameter)
Calculated Orbit: 892.7 km altitude
Conclusion: Does not match Saxton's calculations.

"Falcon Approaching Endor" (Source: R.S. Anderson)

Calculated Distance to Endor (14.48°): 41,261.6 km
Calculated Distance to DS2 (1.66°): 31,065.1 km (using 900 km diameter)
Calculated Orbit: 4,996.5 km altitude
Conclusion: Does not match Saxton's calculations.

"Death Star Holo #1" (Source: Original)

(Note: Using this requires the assumption that the holographic display is to scale.)
Calculated Virtual Distance to Endor (23.97°): 25,041.5 km
Calculated Virtual Orbit (5.69°): 2,541.7 km (side view allows angular width of orbit to be compared to angular width of Endor)
Calculated Virtual Size of DS2 (2.01°): 880.8 km diameter
Conclusion: Consistent with Saxton's calculations (i.e., less than 10% error on orbital radius and diameter of DS2)

"Death Star Holo #2" (Source: Original)

(Note: Using this requires the assumption that the holographic display is to scale.)
Calculated Virtual Distance to Endor (50.56°): 12,176.8 km
Calculated Virtual Orbit (19.86°): 3,855.2 km (side view allows angular width of orbit to be compared to angular width of Endor)
Calculated Virtual Size of DS2 (9.93°): 2,019.3 km diameter
Conclusion: Does not match Saxton's calculations.

Conclusion on Saxton's Calculations

Only one of these four images, "Death Star Holo #1," seems to match Saxton's size of 900 km diameter and orbit of 2,000 km altitude. No "live" shots match his calculations. Furthermore, the holographic display itself cannot be considered to be to scale: "Death Star Holo #2" shows an orbit approximately 17% larger, while the DS2 itself is now 129% larger. Clearly, these two holo images cannot *both* be to scale, and there is no way to know if *either* is intended to be to scale. (This does make sense, though: The briefing seemed to be used to give everyone the "big picture" – specific tactical considerations such as sector assignments, formations, attack vectors, and so forth were

not discussed, so there would be no need for the holographic display to be to scale. Specific assignments along with more useful details would probably have been handed out by individual squadron commanders or ship captains in individual unit briefings.)

Therefore, the only image that supports Saxton's conclusions must itself be rejected as a reliable source of information. In the following section, I will calculate the apparent size of the DS2 using canonical sources, compare them with official sources to determine which, if any, can be accepted, and then determine the correct orbit of the DS2.

The Size and Orbit of the Second Death Star

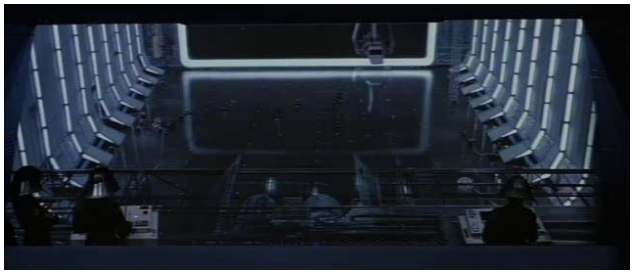
In this section, I calculate the size and orbit of the DS2 using canonical sources only. Using this data, I can calculate the upper limit of debris that can reach the surface of Endor itself in the following section.

Hangar Bay, Waistband Trench, and the Size of the Second Death Star

Saxton explains his methodology for determining his "lower limit" for the size of the DS2, so I will quote him directly:

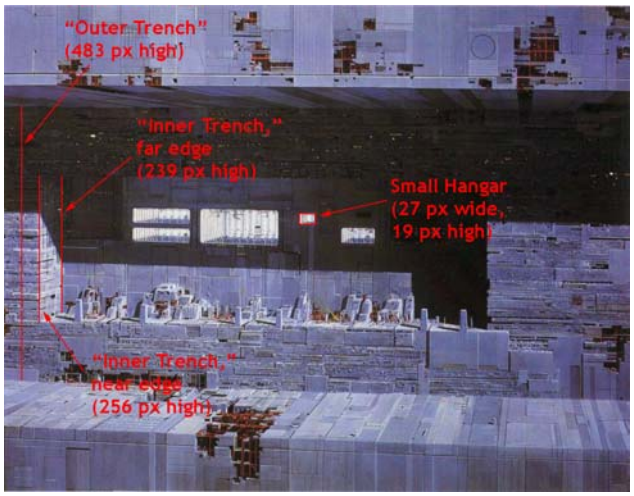
> The equatorial "waistband" trench of the *Death Star II* can be compared to the diameter of the whole battle station in photographs taken from astronomical distances. The local area around the docking bays used by the Emperor and Lord Vader can be measured approximately by scaling the shuttle with surrounding features. (The height of a landed shuttle is approximately 23m.) This local area appears to be somewhere inside the waistband trench; which enables us to calculate a lower limit on the size of the *Death Star II*.
>
> A detailed image of the whole battle station appears in *The Art of Star Wars: Episode VI*. In this large scan ["Death Star – Large"], the polar diameter is 1682 pixels, the equatorial diameter is 1686 pixels and the height of the equatorial trench is 11 pixels (in the well illuminated region near the middle of the picture). That means that the diameter of the *Death Star II* is about **153±7** times the width of the waistband trench, whatever that may be.
>
> The height of Lord Vader's hangar can be determined from images taken during Luke's escape. In this image ["Shuttle Escape"] the shuttle is about 85 pixels high (extrapolating the additional height of landing gear), and the bay aperture is about 244 pixels high. According to published blueprints, the shuttle is about 22.25m high, and therefore the hangar aperture is 64m high. (Similarly the width of the aperture is approximately 237/42 times the shuttle's closed wingspan, according to this image ["Shuttle Landing"] taken when the shuttle was exactly at the entrance.)
>
> Vader's is the smallest hangar in the vicinity. The Emperor's is 62/18 times higher. The bays are all set back into a rectangular notch, which itself is within a deep notch in the hull of the station. Neglecting the displacement of the hangars away from camera, this image ["Death Star Landing Bays"] shows that the inner and outer notches are respectively 260/18 and 501/18 times the height of Vader's hangar, or approxoimately [*sic*] 0.92km and 1.8km.
>
> The outer notch cannot be higher than the total height of the equatorial trench. If it were itself the equatorial trench then the entire battle station would have a diameter of about **270km**.

As Saxton notes, his calculations are made without accounting for "the displacement of the hangars away from the camera." In this section, I correct this by taking relative size into consideration during my calculations. Furthermore, instead of Saxton's "Death Star – Large" image, I use a shot taken directly from the movie, thereby allowing angular width to be more accurately calculated. Finally, I use a new shot of Vader's shuttle landing on the DS2 ("Shuttle Landing – New") wherein the "wing hinges" (i.e., the forward edge of the widest part of the main hull) are directly over the hangar bay entrance. (I am using Saxton's width of the wing hinges, 12.1 meters, as my "ruler" for measuring the hangar bay, so I want that part of the shuttle to be exactly as distant as the hangar bay door itself.) Let's first take a look at "Shuttle Landing – New":



The shuttle is 38 pixels wide across the wing hinges, while the bay itself is 244 pixels wide. Given that the shuttle is 12.1 m wide across the wing hinges (using a metric conversion of the landed width, in feet, from the movie set blueprints), this means that the hangar bay must be **77.7 m (73.2 – 82.7 m) wide**. (Again, note that all measurements are given assuming a margin of error of ±2 pixels.)

Now, using this value for the width, we can calculate the size of the trench. Consider the measurements on "Death Star Landing Bays" (Source: Saxton):



Given that the small bay is at the same relative distance as the inner trench's *far edge*, the inner trench must have a height of 239/27 times 77.7 m (73.2 – 82.7 m) meters, or **687.8 m (598.2 – 797.2 m)**. Then, given that the *near edge* of the inner trench is at the same absolute distance as the outer trench, we know that the outer trench must be 483/256 times 687.8 m (598.2 – 797.2 m), or **1297.7 m (1115.2 – 1522.2 m)**. (This is noticeably smaller than Saxton's width of 1,800 meters, but the difference is generated by taking relative distance into account.)

Finally, this width can be used in "Death Star Approach – Breaking Off" to determine the real size of the DS2:

The trench, measured at the horizon, has a size of 15 pixels (0.47°), yielding a distance of 158.2 km (119.9 – 214.3 km) to the DS2 horizon. Then, given that the DS2 has a size of 1979 pixels (56.85°), allows us to calculate the DS2 radius at 85.6 km (64.8 km – 116.1 km). Thus, the diameter of the DS2 is **171.2 km (129.6 km – 232.2 km).**

The DS2 is most commonly attributed a diameter of 160 km (*Movie Trilogy Sourcebook*, *Special Edition Movie Trilogy Sourcebook*, *Death Star Technical Companion*, StarWars.com Databank). This size falls within the expected margin of error calculated from canonical sources (129.6 – 232.2 km); therefore, we fail to reject the official size of 160 km for the DS2. (However, we do reject an interview, cited by Saxton, that would have put the size of the DS2 at approximately 500 miles or 800 km in diameter – this figure clearly does not fall within the margin of error calculated directly from the canon.) Therefore, throughout the remainder of this article, **we accept the official size of 160 km diameter as being correct for the DS2**.

Orbit of the Second Death Star

Recall the screen shot "Death Star over Endor." Now that we have an accurate size for the DS2, we can easily calculate its distance from the camera in that shot. Given an angular width of 21.71°, the DS2 is 424.8 km (420.6 – 428.9 km) distant. Given the distance to Endor, calculated earlier at 7616.1 km, the orbital radius of the DS2

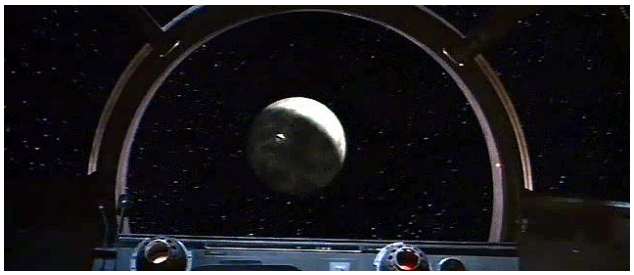
can be shown to be 7311.5 km (7308.6 – 7314.4 km) in radius, or 2111.5 km (2108.6 – 2114.4 km). To verify this orbit, I use another low-orbit shot ("Death Star over Endor #2," Source: R.S. Anderson):

Using the same techniques described previously (and further detailed in the Appendices), this photograph yields an orbit of 7350.3 km (7346.7 – 7353.8 km) radius, or 2150.3 km (2146.7 – 2153.8 km) altitude. This is very close to the 7311.5 km (7308.6 – 7314.4 km) radius figure calculated from "Death Star over Endor," but the orbits don't quite overlap. Given that orbits are rarely perfectly circular, this is acceptable. I will use the average of the two values (**7330.9 km radius, 2130.9 km altitude**) throughout the remainder of this article.

Explaining the Shots from the Fleet Emerging from Hyperspace

Correction:
In the original version of this article (05/31/2004), I had used these shots to estimate the orbit of the DS2 at 38,824.7 km radius (33,624.7 km altitude). My reasoning was that they show the entire disc of both the DS2 and Endor (making measurement subject to less error), and both shots seem to be consistent with each other. Since this shot had the ribs of the *Falcon's* cockpit canopy visible, it seemed to be the most reliable shot because the range of possible zoom factors is constrained. However, "Darth-Wong" demonstrated that this shot of *Tyderium* approaching Endor has the same constrained foreground, making the original calculated orbit impossible. In this section, I propose a hypothesis that may explain the discrepancy.

There is, however, an apparent contradiction in this shot ("Falcon Approach," Source: R.S. Anderson):



If you measure this shot assuming a normal 70-degree view, the DS2 has an angular width of 1.66°. Given the 160 km diameter, this yields a distance of 5522.7 km. Endor, at 14.48°, is calculated to have a distance of 41,261.6 km. As both are almost centered in the frame, we would calculate the DS2's orbit at 35738.9 km radius (30538.9 km altitude). This is an orbital radius **4.9 times as large** as the one calculated earlier.

In my opinion, there are only a few possible explanations for this:

1. The DS2 moved – highly unlikely because a change of tens of thousands of kilometers would have revealed that it was operational while the fleet was on approach.
2. Optical distortion – a fish-eye lens (approximately 150° angle of view) could distort the DS2 and Endor to make them appear farther apart; however, the objects in the cockpit show no comparable distortion, making this highly unlikely.
3. Hyperspatial distortion – a very large number of capital ships and starfighters had just emerged from hyperspace in the moments before this shot, so perhaps some unknown physical laws are at work.
4. Blooper – the shot simply doesn't match because the matte painting artist didn't get the scaling quite correct. (Saxton discusses bloopers in "Continuity, Canon, and Apocrypha".)

As #1 and #2 both seem to be very hard to justify, that only leaves #3 and #4. "Blooper" is an "if-all-else-fails" category (i.e., only use it if there is no way whatsoever to justify the apparent canonical discrepancy). Therefore, let's take a closer look at #3. First, in the transition from hyperspace to realspace, Endor and the DS2 both appear on screen, first at a great apparent distance, but very quickly zooming closer. Does this represent real movement in realspace, or is it a visual distortion caused by the shift from hyperspace to realspace? Either is possible. In

fact, if it were the latter, it would be possible that some of this distortion was still present a moment later in the "Falcon Approach" shot. (Saxton actually wrote a fairly extensive article on hyperspace and noted that visual distortion does appear to occur in other cases, as well.) Therefore, I propose that this is the best way to explain this shot.

Death Star Explosion and Aftermath

Explosion and Implosion

As noted earlier, *Star Wars Insider* #76 claims a direct link between the wormhole proposed to exist in *The Glove of Darth Vader* and the survival of Endor. Saxton claims to have investigated this possibility:

> It has been asked whether the total mass of the battle station's remains was great enough so that the fireball could fall back inwards upon itself due to self-gravity, perhaps to be swallowed by whatever exotic residue the reactor core may have left. Unfortunately, if this were the case, **the outward motion of the margins of the fireball would have slowed visibly during the time shown in the movie**. Empirically, it did not. [emphasis added]

In this section, I attempt to verify his claim that that outward motion of the margins of the fireball did not slow visibly. The following screen shots show the DS2 immediately before the explosion, the first frame of the explosion, and then half-second intervals thereafter. In each shot, I superimpose a semi-transparent circle to mark the location of the outermost extent of the fireball. (Individual chunks of coarse debris are not included within this circle, nor are the trails of debris that follow them.)

(Before explosion)

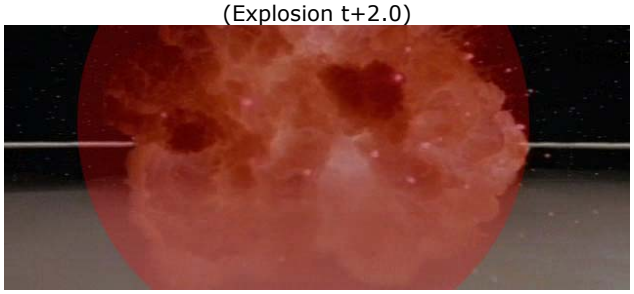
(Explosion t+0.0)

(Explosion t+0.5)

(Explosion t+1.0)

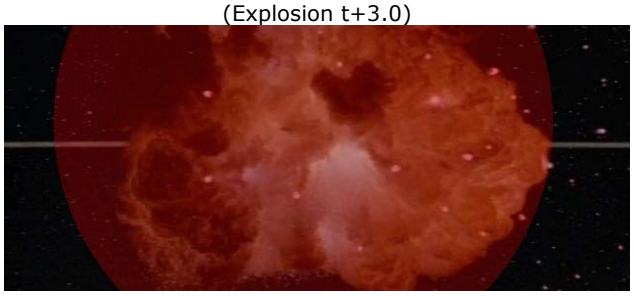
(Explosion t+1.5)

(Explosion t+2.0)

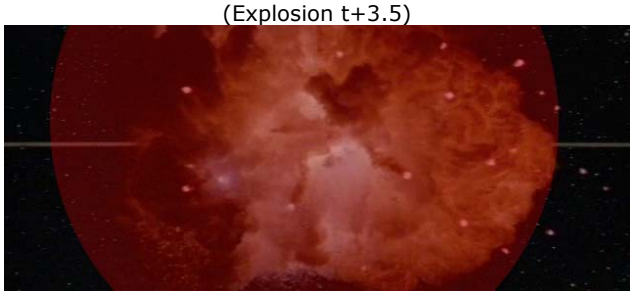


(Explosion t+2.5)

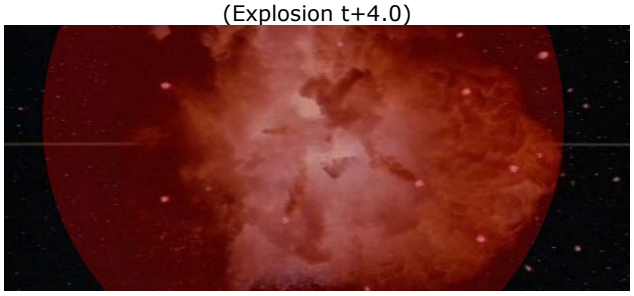
(Explosion t+3.0)



(Explosion t+3.5)



(Explosion t+4.0)



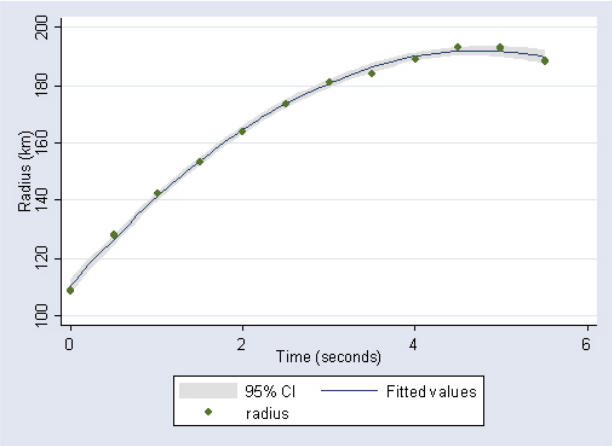
(Explosion t+4.5)

(Explosion t+5.0)

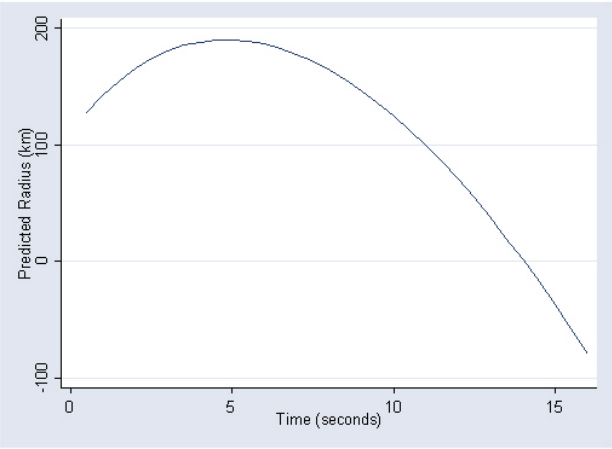
(Explosion t+5.5)

Visual inspection of these shots seems to indicate that the fireball *does* actually slow down; however, this observation directly contradicts Saxton's claim. To better analyze this phenomenon, I conducted a regression analysis of the time, radius, and velocity of the fireball. (Regression, in the simplest terms, is a statistical technique that analyzes the effect of one or more independent variables on a dependent variable. It calculates the coefficients that would result in the best possible prediction; specifically, it minimizes the square of errors between

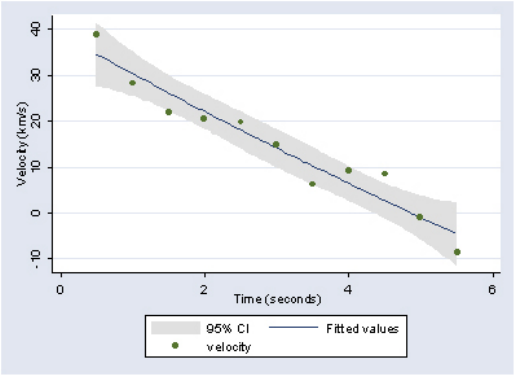
the predicted values and the observed values). The following calculations and graphs were made using Stata 8.0. Consider this graph showing the plot of radius of the fireball (in km) against time (in 0.5 second intervals):



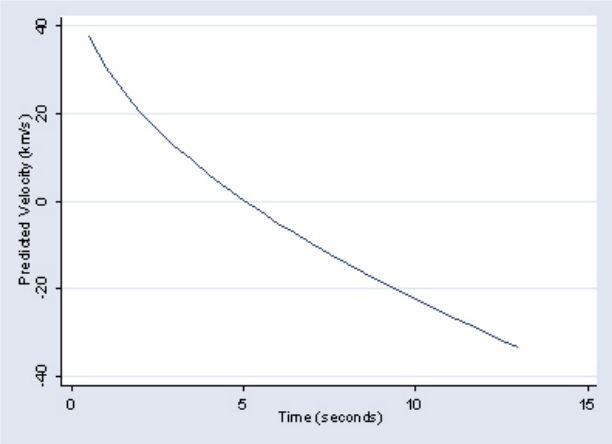
The green diamonds represent actual recorded distances, as taken from the screen shots. The blue line represents the fitted curvilinear relationship between distance and time, and the gray area around that line represents the 95% confidence interval for this curve (i.e., there is a 95% chance that the "real" curve is somewhere in that gray area). Notice how this fits the form of a quadratic equation (i.e., $y = ax^2 + bx + c$), in this case with the coefficient *a* being a negative number (and thus resulting in a decreasing slope as time increases). Now, consider this graph showing the predicted radius of the fireball over time, extending this curve outward over the next several seconds:



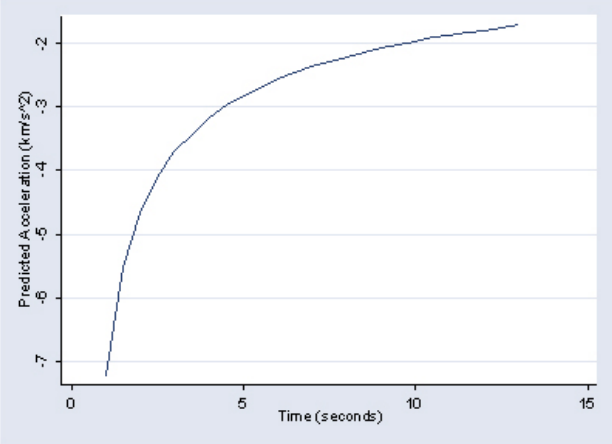
Thus, if the observed changes in the growth of the fireball continue, we should expect the fireball to implode (i.e., be reduced to a radius of 0 km) at approximately t + 14 seconds. This deceleration is not actually constant – it decreases slightly in strength over time. Consider this regression curve for velocity over time:



This shows a curvilinear relationship wherein velocity decreases over time, and the rate of decrease (deceleration) seems to drop off slightly over time (i.e., the slope smaller). This curve can be extended outward (as before), yielding the following predicted velocity over time:



The predicted acceleration (or deceleration, in this case) can also be plotted:



In other words, the rate of deceleration is fading over time, but it will not approach zero until considerably after the fireball implodes at approximately t + 14 seconds.

Given the characteristics observed above, we can draw a few conclusions about this implosion force. Most significantly, it is clearly *not* driven by gravity, at least not as it is understood to modern-day physics. The acceleration drop off over time does not appear to be related to the square of the distance from the center of the fireball, whereas a gravitational force would. (Acceleration due to gravity = Gm_1m_2/d^2, where G is Newton's gravitational constant.) The mass required for the acceleration observed would likewise be impossible – the DS2 would need a mass considerably greater than the moon of Endor, by at least an order of magnitude. Even if such a mass only "appeared" during the explosion, it would literally pull everyone off the surface of Endor at a force of several *g*'s. Clearly, this did not occur, so its effects must not extend as far as the surface. (They could, possibly, have extended as far as the fleet, if one assumes that the sublight drive systems in the *Star Wars* universe could resist the pull.) Furthermore, we can safely assume that this force did not exist *prior* to the explosion of the DS2; the accelerations observed are measured in kilometers per second, hundreds of times the pull of normal gravity. (If it *did* exist, it would have to have been offset by some kind of inertial dampening field – in that case, it would *technically* exist, but its effects would not be observed.)

Thus, we can conclude the following about the implosion: 1) it is not significantly affected by distance; 2) there may be some kind of field around it that contains the force (or just an outer limit of its effects), shielding the surface of Endor from its effects; 3) it did not have any significant effect until the DS2's explosion; 4) its strength faded relatively quickly over time. These observations and conclusions seem to satisfy one of Saxton's objections to any such implosion: "In any case, the mass needed for self-collapse would have been much greater than that of the Endor moon itself, and the station's everyday tidal effect would have warped the moon's shape noticeably." As

we have determined it is *not* gravitational in nature (and therefore not related to mass), Saxton's objection is satisfied.

In conclusion, this implosion, *clearly observable in the canon itself*, is evidence in favor of the wormhole cited in *Star Wars Insider* #76 and *The Glove of Darth Vader*. Saxton's objections against such an implosion have been satisfied because 1) the fireball clearly does decelerate over time and 2) the force causing the implosion is clearly not gravitational in nature.

Hypermatter and Wormholes

Why might a wormhole appear? In the Star Wars universe, wormholes are rare but not unknown. The Emperor used a Force storm to create a wormhole that transported Luke Skywalker from Coruscant to Byss in *Dark Empire*. The hypergates used by the Gree (*Star Wars Adventure Journal* #8) also share some characteristics of wormholes, allowing an individual to be instantaneously transported from one gate to another. Of course, the presence of the Endor Gate (*Star Wars Gamer* #9) provides some justification for such an event by establishing that it has a history of creating hyperspatial anomalies, including wormholes that caused starships to suddenly appear on the far side of the Galaxy.

Still, the DS2 explosion itself may have been partially (or even wholly) responsible. Let's consider the following hypothetical explanation: The Death Stars are described as using "hypermatter" reactors, and in *Star Wars Attack of the Clones Incredible Cross-Sections* (written by Saxton) hypermatter reactors are described as involving superluminal particles (i.e., faster-than-light). Something can be considered faster-than-light in one of two ways: It can have an imaginary mass, thereby allowing it to literally move faster than the speed of light (e.g., the hypothetical particles called tachyons) or it can have an *apparent* velocity that is faster than the speed of light (e.g., something moving through hyperspace). This, along with the similarity of the terms "hypermatter," "hypermass," and "hyperspace," certainly implies some qualitative connection between them. Therefore, I propose that the hypermatter reactor on the DS2 somehow draws its power from particles in hyperspace – perhaps a self-contained bubble – and doing so would theoretically require that some kind of hyperspatial opening be maintained. After the reactor is destroyed, artificial hyperspatial opening is no longer controlled – it essentially rages out of control, pulling everything nearby (a minimum of a couple hundred kilometers radius) into it. This uncontrolled hyperspatial opening (or the hypermatter that was contained within it) creates a wormhole that leads to the other side of the galaxy, ejecting the consumed remnants of the DS2 in the Mon Calamari system. This hyperspatial opening is collapsing, however, as shown by the drop off in deceleration; eventually, it closes altogether, probably within the next several minutes (or, at most, hours).

Thus, there is at least a *plausible* explanation (subject to the limitations of dealing with unknown laws of physics) that would explain how a wormhole might form out of the DS2 explosion as described in *The Glove of Darth Vader*, even if the Endor Gate explanation were not directly responsible. The wormhole ejecting matter on the other side of the galaxy also answers another of Saxton's objections to such an implosion: "Leia did not encounter any self-collapsed remnant when she visited the place where the station would have been five years later, in *Dark Force Rising*." Given that there would be no "self-collapsed remnant" to find, this is not a problem.

We still need to establish how much, if any, debris escaped the wormhole and may have reached Endor itself. This topic is discussed in the following section.

Debris

If there has not been a wormhole, how much of the DS2 would hit Endor? At the calculated orbit of 7330.9 km radius, Endor subtends 90.36° (about 14.8% of the sky). In the case of a "hard" explosion (i.e., debris is propelled beyond escape velocity), only that debris that moves directly toward Endor will hit the moon. Therefore, we can conclude that 14.8% of the DS2's mass would hit the moon — barring the implosion described earlier, of course. How much mass is that? If the DS2 were a perfect sphere with a diameter of 160 km, it would have a volume of 2,140,000 km^3. Saxton and starwars.com both refer to the DS2 as "half" built, so I will arbitrarily cut that volume in half (1,070,000 km^3) to account for unfinished portions of the station. Thus, we can calculate the maximum volume of debris that could hit Endor: 1,070,000 km^3 x 0.148 = **158,360 km^3**.

If this were all "fine" debris (i.e., matter that would essentially create "soot" in the atmosphere) and if the debris compacted at about a 10 to 1 ratio (i.e., we assume that the DS2 is approximately 90% hollow), this would be enough debris to cover the surface of Endor to a depth of 31.5 centimeters. By comparison, Saxton's original estimate (also using the 10 to 1 compaction ratio) was a layer of debris "a few dozen" meters thick over the entire surface. Clearly, this would be a much less significant event – but still an environmental disaster.

What about "coarse" debris (i.e., large fragments that could actually strike the surface instead of burning up in the atmosphere)? Saxton counts "at least fourteen" large fragments, any one of which would cause an impact as big as or somewhat smaller than the one that killed the dinosaurs on Earth 65 million years ago. (The size of these fragments seems to range up to perhaps 5–10 km.) Unlike an asteroid, however, these fragments may not have been solid (again, refer to the 10 to 1 compaction ratio proposed by Saxton) and we do not know the material composition of the DS2, so the exact kinetic energy from such an impact isn't completely certain. Nevertheless, we can make a few reasonable assumptions to create an estimate that would probably be accurate within one or two orders of magnitude. If these coarse debris chunks did indeed have a 10 to 1 compaction ratio, and if they had a density similar to titanium (4.50 g/cm^3), then the largest chunks (~10 km diameter) would have

a mass around $2.36x10^{11}$ metric tons. If they hit the surface at about 10 km/s, the kinetic energy would be about $2.36x10^{22}$ joules – the equivalent of **5,609,986.9 megatons of TNT**.

However, Saxton makes a very good point about such large impacts:

> The apparent tranquility of the site around the demolished shield generator, where the rebel commandoes celebrated their victory, has implications for the size distribution of the debris particles. **The debris chunks which would have directly collided with the ground team must have been deflected to other areas of the moon's surface by the screening rebel fleet.** However an impact over a certain size will cause a rain of ejecta and seismic concussion which would have harmed the commandoes even if they were dozens, hundreds or even thousands of kilometres away. This suggests that apart from the fourteen or so visibly large fragments, most of the impacting debris comprised bodies no larger than a dozens or a few hundred metres across, whose impacts would have no more effect on the rest of the globe than thermonuclear detonations. Much of the mass of the battle station probably fell as centimetre-sized or smaller grains, burning in the air and directly entering the atmosphere as dust without striking ground. [emphasis added]

Expanding on his comments, consider that the area of Endor that would be hit by DS2 debris is 49,384,702.5 km^3, only about 7,929.6 km across if measured along the surface. An impact of that magnitude (~5.6 million megatons) would have an almost immediate catastrophic impact on everything within that range (and, indeed, the whole moon) – including the rebel commandos. Again, this fits Saxton's quote, above – the rebel fleet *must* have screened and intercepted the largest chunks of debris. Tractor beams may have been used to push the chunks into a different trajectory and/or turbolasers could have been used to break up the largest chunks. (Capital ship firepower is illustrated in *The Empire Strikes Back* when a star destroyer is vaporizing entire asteroids with a single shot.) Given that the Rebel fleet is between the DS2 and Endor at the time of the explosion, there is no specific reason to think that this did *not* happen.

Of course, all of this represents what would occur if the wormhole did *not* exist. The wormhole's effect on the amount of debris reaching Endor is discussed below.

How Much Debris Escapes the Wormhole?

Put simply, there is no way to be sure how much, if any, escapes from the wormhole, given the canonical data available. The fireball itself, making up the bulk of the DS2's remains, should be completely pulled into the wormhole. Given that the outer surface will collapse at approximately t + 14, we can safely conclude that slower-moving particles beneath the surface will as well. (Saxton: "Matter hidden below the surface [of the fireball] expands at the same or slightly lower velocity.") This would seem to leave, at most, the 30+ observed solid chunks. These chunks appear to have a higher initial velocity (perhaps 80+ km/2), meaning they *may* escape from the hyperspatial pull that is collapsing the rest of the debris. (Again quoting Saxton: "At least thirty multi-kilometre solid chunks emerged from and overtook the roiling debris cloud. Their velocities are greater than [that] of the cloud's general expansion.") Still, even at an initial velocity of 80 km/s, the fastest-moving chunks of debris would get no farther than 500 km from the DS2 (i.e., only about one-quarter the distance to Endor's surface), given the deceleration observed and calculated earlier.

Still, there is no way to be certain *how much* actually escapes – the observed deceleration from the wormhole is potentially strong enough to eventually stop even the fastest chunks, but there is no way to know how far the wormhole's implosion force extends. Since the canon itself provides no clue to how much, if any, debris escapes this implosion, I'll turn to official sources for clues:

> The explosion of the second Death Star filled the Forest Moon's orbit with **thousands of tons of debris**, ranging from pebble-sized bits to 100-meter sections of the space station. While a few chunks fell onto the Forest Moon, the satellite was spared any significant environmental damage. ("Endor and the Moddell Sector," *Star Wars Gamer* #9, p.35, emphasis added)

Therefore, at minimum, "thousands" of tons of debris escaped the wormhole. Given the size of the DS2 and the titanium-like density suggested earlier, it would have a mass of approximately $4.28x10^{14}$ metric tons. "Thousands" of tons could mean that as little as 1/428 billion of the debris escapes the wormhole. However, if we assume that only a fraction of the debris that escapes the wormhole would end up in orbit, we would increase our estimate. The most conservative ratio of surviving material to orbiting material that I consider even possible is about one million to one, meaning that all the rest (99.9999%) is not propelled in such a way that it enters a stable (or even unstable) orbit. If this were true, billions of tons ($1.0x10^9$ to $9.9x10^9$ metric tons) escape the wormhole.

Therefore, given these assumptions, we can calculate the mass of debris that actually enters Endor's atmosphere as being, **at most**, 1/500,000 as large as our earlier estimate: approximately 316,720,000 m^3, or (at titanium-like density) 1.43 billion metric tons. This is a huge amount of pollution: It is considerably more than a normal volcanic eruption (Mt. St. Helens ejected approximately 500 million metric tons into the atmosphere), but it is somewhat less than the 2 billion metric tons of industrial pollution produced each year on Earth. Still, it is not enough to cause any long-term environmental damage. It would, however, probably lower global temperatures by up to a few degrees. This fits the quote from *Star Wars Gamer* #9: "The satellite was spared any **significant** environmental damage." (emphasis added) Again, this represents an **absolute upper limit** to the amount of

debris that can reach the surface of Endor; the actual amount of debris to escape the wormhole may have been considerably less.

Conclusion

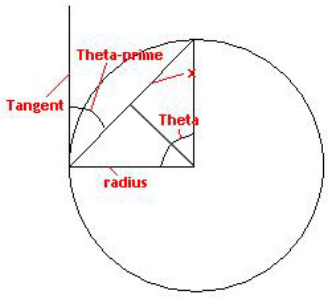
As shown in this article, the canonical evidence does not require or support the "Endor Holocaust" theory; furthermore, the official material on Endor and the aftermath of the explosion of the Second Death Star has been validated by the canon itself. Measurements of the implosion demonstrate that the canon itself does not require that *any* debris strikes the surface of Endor; still, official material suggests that at least *some* debris reaches the surface, so that it the interpretation I believe is most acceptable.

As Saxton himself said, "Only reject existing material where absolutely necessary." I believe that this article demonstrates that it is not necessary to reject the official post-Endor events. In summary, this conclusively proves that the "Endor Holocaust" never happened – it only existed in Imperial propaganda and empirical oversights.

Appendix 1: Calculating the total size of a circle given the length of a bisecting line

To calculate the size of a circle (or, in our case, the horizon of a sphere), first measure the length of the line (x) that intersects the circle. (See diagram.)

Then, draw another line tangent to the edge of the circle. Measure the angle (theta-prime, or θ') between the tangent and the intersecting line. The angle of the arc (theta, or θ) is equal to 2 x θ'. For example, in the picture above, θ' is 45 degrees, so θ is 90 degrees.



Next, draw a line that bisects the triangle formed by the radius (both legs) and the intersecting line. Now you have two right triangles with an angle of 0.5 θ with the opposite side's length equal to 0.5 x. If you take the sine of this angle, you get the ratio of the opposite side (0.5 x) to the hypotenuse (radius). Therefore, you can solve for the radius using this formula:

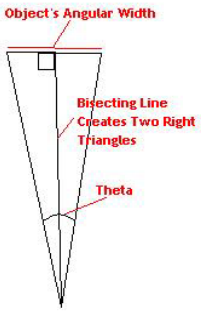
$$\text{radius} = (0.5\ x) / \sin(0.5\ \theta)$$

Thus, using this methodology, I was able to calculate the relative size of Endor's visible disc even when only a fragment of the horizon is visible.

Appendix 2: Angular Width, Size, and Distance

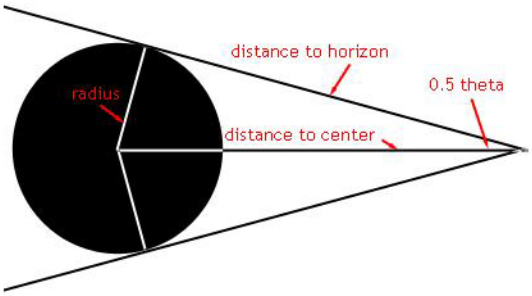
Imagine that you are looking at a distant object. The diagram below draws lines between your eyes and the object's edges, making a triangle.

If you were to bisect this triangle, you'd have two right triangles with one leg equal to 0.5 * (object's width) and the other leg equal to the distance from you to the object, with an angle of 0.5 θ. Recall the definition of a tangent in trigonometry: It is the ratio of sine to cosine, or, after dividing out the value of the hypotenuse, it is the ratio of opposite side to adjacent side. Thus, tan (θ/2) = (width/2)/distance.

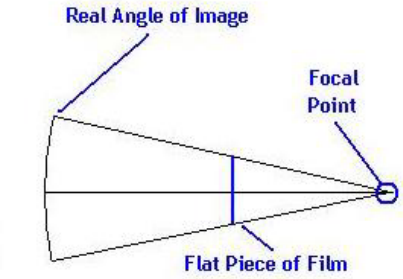


Spheres are handled a little differently – being round, they have a horizon that will always appear somewhat closer to the viewer.

Thus, the correct formula for a sphere is sin (θ/2) = radius/distance to center. The horizon can also be calculated by cos (θ/2) = distance to horizon/distance to center.



Film shots, however, are flat projections of a three-dimensional space; therefore, it is sometimes necessary to correct for possible distortion in the image. To do this, you note the width, in pixels of the image and compare that to its angular width (70° for a normal widescreen movie shot). Then, using the tangent method described earlier for flat objects, figure out where the focal point would be (measured in "imaginary pixels" above the image).



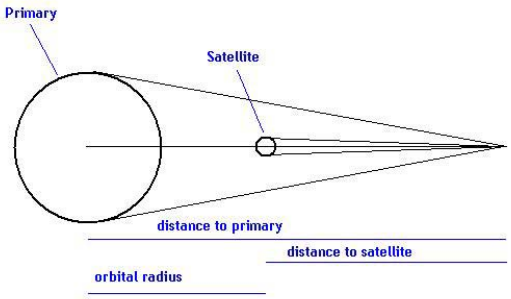
Using this virtual focal distance, you can calculate the real angular width of an object in a picture as 2 * $\tan^{-1}$((width/2)/focal distance). In most pictures, this will make little or no difference – the distortion in a 1° image is negligible. However, it is very important when calculating the total angular width of an object that is only partially on-screen (e.g., using the circle formula described in Appendix 1 to calculate the off-screen total size of Endor's disc in the "Death Star over Endor" shot).

Thus, counting pixels can yield the angular width of the DS2 and Endor; this, in turn, allows you to solve for either distance or size (but you must know one of the two values to do so).

Appendix 3: Calculating Orbits

In the case of the satellite being superimposed and nearly centered over the primary, we have the situation illustrated here.

This is the easiest to solve: Simply subtract the viewer's distance to the satellite from the viewer's distance to the primary, yielding the orbital radius.



In the case of the satellite being superimposed over the primary's horizon, the situation is a little more complicated, but still easy enough to solve. First, you figure out the distance from the satellite to the horizon, as illustrated above. This distance is one leg of a right triangle (the other leg being the primary's radius and the orbital radius being the hypotenuse). Thus, you solve this using the Pythagorean Theorem: Orbital radius = $\sqrt{((\text{primary radius})^2 + (\text{distance from satellite to horizon})^2)}$.