

High Dynamic Range Digital Imaging of Spacecraft

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Abstract

The ability to capture engineering imagery with a wide degree of dynamic range during rocket launches is critical for post launch processing and analysis [USC03, NNC86]. Rocket launches often present an extreme range of lightness, particularly during night launches. Night launches present a two-fold problem: capturing detail of the vehicle and scene that is masked by darkness, while also capturing detail in the engine plume.

Categories and Subject Descriptors (according to ACM CCS): I.4.1 [IMAGE PROCESSING AND COMPUTER VISION]: Digitization and Image Capture — Quantization

1. Introduction

Figures 1 and 2 illustrate a debris event as displayed in an 8 bit representation during a spacecraft night mission. Figure 1 captures debris to the left and above the vehicle in the night sky, illuminated by the engine plume. Figure 2 includes debris in front of the engine plume.

The exposure was set to capture detail in the flame, while the limitation in dynamic range results in little to no observable detail in the vehicle area. While the debris can be observed in and near the plume area, there is a loss of useful visual information as to the origination point from the vehicle, how the debris was generated, and the remaining state of the vehicle. Detail of the debris itself is also reduced as a result of the limited dynamic range, amongst other factors such as image resolution and optical system sharpness.

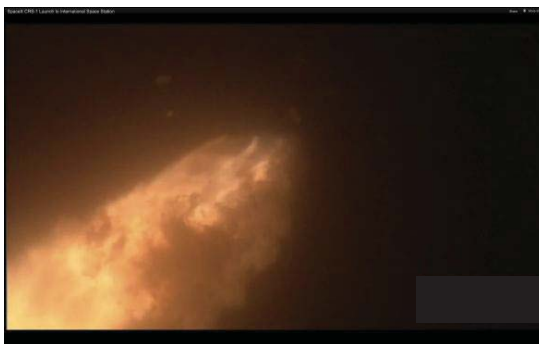


Figure 1: Engine Debris Upper Left of Plume during Night Mission



Figure 2: Engine Debris in Front of Plume during Night Mission

2. Space Shuttle Era Engineering Imagery

During the Space Shuttle Program, Engineering Imagery was primarily collected through the use of 16mm and 35mm high speed film cameras. Testing of HDR digital image capture began in 2009, in preparation for an eventual film to digital transition.

2.1 Initial Attempt

Two 8 bit HD1100 2/3 inch sensor industrial cameras with similar fields of view during STS-129 [SHK*09] (See Figures 3 and 4).



Figure 3: HD1100 Cam A (1/60 exposure)



Figure 4: HD1100 Cam B (1/300 exposure)

2.2 RED ONE M

The cameras were configured for STS-131 [SHK*10a] to acquire imagery of the launch from five camera sites around the pad perimeter (see Figures 5 and 6). Deployed in pairs to each site, the cameras provided imagery not only for HDR testing purposes, but also to generate stereoscopic 3D image sets.



Figure 5: RED ONE Composite of 5 Camera Sites



Figure 6: RED ONE Camera Site 3 Single Frame

The RED ONE M experiment was successful in illustrating the capability of single exposure digital imagers at that time. Lab testing has shown that the RED ONE M has a dynamic range of 10.4 stops with 0.5 stop RMS noise, Log mode.

2.3 Two HD1100 High Definition Cameras

These cameras with matched 80in focal length Meade telescopes were again used for a dual imager HDR experiment during STS-132 [CHK*10b].



Figure 7: HD1100 Cam A (f/10 exposure)



Figure 8: HD1100 Cam A (f/20 exposure)

The HDR image generated from the HD1100 exhibited some detail over a greater range than did imagery from either camera individually (see Figures 7 and 8).

3. STS-135 Final Space Shuttle Flight

A number of digital images were acquired to capture the final Space Shuttle flight of STS-135, including the Phantom HD Gold HSD, RED ONE M, RED EPIC, Cooke Dimax HSD, Photron SA1 and SA2 HSD, and ARRI Alexa [HKPO*11].

3.1 RED ONE M 4K

A RED One 4K camera was deployed to the infield location near camera site 4 as shown in Figures 9 and 10. A 25 mm RED lens was used for the wide angle field of view. The resulting imagery was as expected, similar in dynamic range response to previous tests.



Figure 9: RED ONE M 4K Setup



Figure 10: RED ONE M 4K Sample Frame

3.2 ARRI Alexa

Lab tested for 13.9 stops at a 0.5 stop RMS noise, Log mode (Figures 11 and 12).



Figure 11: ARRI Alexa Setup



Figure 12: ARRI Alexa 120 FPS Sample Frame

3.3 RED EPIC

Lab tested for 11.5 stops at 0.5 stop RMS noise, LogFilm mode (HDR not yet utilized), Figure 13.



Figure 13: RED EPIC Sample Frame

4. Conclusions

High dynamic range is a critical capability of imaging systems for use as engineering documentation of rocket launches. Digital imaging systems that employ multiple integration times or captures have surpassed the dynamic range capability of film cameras utilized during the Space Shuttle program. The capability and usage of digital imagers requires testing and evaluation, both in a controlled lab environment as well as during actual launch events.

Current work is evaluating emerging HDR video solutions such as the RED EPIC/DRAGON with HDR setting of 6 stops, Figures 14 and 15 [Kar14], and the HDR video solution from the University of Warwick/goHDR. It is clear that future dynamic range workflows will require an examination of the entire digital process from capture to display.



Figure 14: RED EPIC HDR 6 Mode Illustrating Dual Exposure, A Frame



Figure 15: *RED EPIC HDR 6 Mode Illustrating Dual Exposure, X Frame*

<http://vimeo.com/advancedimaginglab/hdr>.
[Accessed 25 January 2014].

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