Computer Science Clinic

Final Report for
SpaceX

Process Time Analysis In Spaceflight

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Team Members

Wendy Brooks (Fall Project Manager)
May Lynn Forssen (Spring Project Manager)
Alix Joe
Rachel Macfarlane

Advisor

Ben Wiedermann

Liaisons

Jesse Keller
Jessica Hester
Jim Gruen

Chapter 1

Background

1.1 Introduction

SpaceX is an American space transport company that designs and manufactures advanced rockets and spacecrafts. The eventual goal of the company is to allow people to live on other planets. SpaceX rockets depend on a variety of software to be successful, including simulations, flight software, and data analysis. Almost of this software is written in-house and is complex enough that subtle problems are often hard to catch and very time consuming to debug.

1.2 Tracing and Debugging

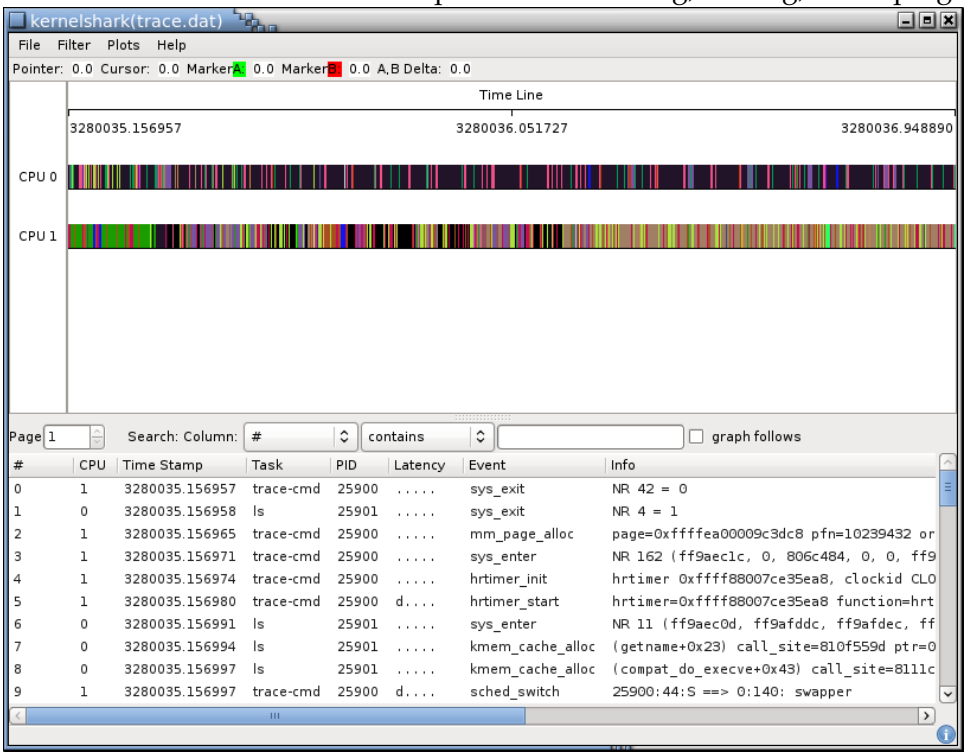
The data that SpaceX developers examine in order to find software bugs is called a kernel trace, which documents the different programs running on a computer over a certain span of time, keeping track of when each program was running on each processor.

In order to find potential bugs in their software, SpaceX developers look for problems like unexpected preemptions, priority inversions, and breaks in the pattern of programs being run. A preemption occurs when one program is running, and is then blocked by another program starting to run on the same CPU. A priority inversion occurs when a high-priority program is indirectly blocked by something of lower priority using up a shared resource that the higher priority program needs in order to run. The software running on SpaceX rockets has deadlines for programs at regular intervals because timing is very important in rocket flight, so when there is a break

in this cyclical pattern of processes this means that there is likely a bug in the software.

1.3 Existing Tool

SpaceX currently uses a tool called kernelshark to visualize this trace data and help find any bugs or anomalies. We were informed by our liaisons that this debugging process can take up to several days, so searching for bugs using this tool uses up a lot of valuable time. Much of the user expeience of kernelshark is outdated or could use improvements. The kernelshark tool consists of a graphical display of the programs running on a computer over time, as well as a tabular view of the same information, in the form of CPU events such as processes switching, waking, or sleeping.



Using only this visualization, it can be difficult to see where the cyclical deadlines for the programs begin and end, making it hard to find when something misses a deadline. In addition, the tabular display of the CPU events in the bottom part of the screen has minimal search functionality

and the different columns of the table are not sortable.

1.4 Problem Statement

Our team will make it easier and faster for SpaceX engineers to find software problems by creating a tool that visualizes rocket data and highlights problem areas. We will create an improved user experience and provide more visualizations of the data than the old tool.

Chapter 2

SpaceShark

2.1 Design

2.2 Architecture

Architecture (overview)

[architecture slide picture helpful here]

Our application has three main portions: the raw input, the parser and itâĂŹs output, and the web-based desktop application. The sections are modular, and as long as output/inputs remain the same, internal changes to one section will not affect the other at all.

Trace-cmd Data is collected by using a command-line utility called trace-cmd. trace-cmd records various events in the Linux kernel while it runs and then outputs this information into a data file with a particular binary format. trace-cmd also has a âĂIJreport" option, which takes an existing trace file and generates a human readable report of this record. Using this format as a starting point instead of the raw binary format simplifies parsing. We decided to leverage trace-cmd report instead of wrestling with the binary data ourselves. This allowed us to make progress faster and to avoid working on an already solved problem.

Unfortunately, the format of the file generated by trace-cmd report is dependent on the version of trace-cmd used. To be able to reliably parse data and add additional information about preemptions, we need our input data to have a consistent format. This creates a dependency on a particular version of trace-cmd. Our liaisons have been using trace-cmd version 2.2.1, so our parser expects input data to be in the format of 2.2.1.

Parser Next the parser takes in this raw data, and ultimately outputs

the data reformatted into JSON with additional information. As a result of the particular version of trace-cmd, we know exactly how the file will be formatted. Each line in the input file is a single recorded event with a number of fields such as task name and pid separated by whitespace. First, we simply break a line on whitespace and extract each of these fields. Then, we can case on the type of event, and based on that we can use the non-standard âĂIJextra informationâĂİ to pull out event-specific analysis. Of primary interest are switch events, where we can pull out which event is switching out and in, and whether or not this was a preemption. (List the specific others?)

The output is formatted as a JSON file, so that we can easily transfer it to the web application. The JSON formatting has these elements:

[see JSON format drive file]

As long as this file remains the same, any changes to the internals of the parser will not affect the application itself. Additionally, this will allow someone with a different output to write their own parser to create the same type of output so that they can view their data in our tool.

We were considering refactoring the parser to be cleaner. Currently, when we extract each field from an event, we immediately format it as a JSON object. This adds some additional complexity in later calculations and analysis, as the JSON object is a key-value pair, and is generally not very space or time efficient. Instead of this, it would be better to create an intermediate format for the data. We imagine this would look like a separate Java class for tasks and events. Events would be subclassed by their type. All events have the same basic information, like the start time, PID of the task involved, and CPU, but their extra information field varies based on type. We imagine that creating event and task classes would make the parser code much more readable, as after grabbing each field from a line, this information would be passed off and dealt with elsewhere. Given enough time, we would refactor the parser in this way, but as it is currently functional, these changes have not been high priority.

Web Application

IndexedDB The application takes the JSON string and loads it into IndexedDB, a browser-based database. IndexedDB is built into most browsers, including node-webkit. More information on the details of IndexedDB can be found here (FIXME put a url?). We are basically using IndexedDB to store strings between pages. It also maintains storage between application sessions. Therefore, we are able to have the choice to load the same file again, without reselecting it. If the user chooses to load a new file, we just write over this. Specifically, we store numCPUs (number of CPUs for this

file), cycleEvents (the events divided into cycles for the cycles page), Tasks (a list of all the tasks with various information), AutocompleteNames (used for autocomplete in search bars), AutocompleteEventTypes (also used for autocompleting), and Events (a listing of all the events). These correspond to the JSON types laid out in the Parser section (presumably we have numbers/pages later).

Using the node-webkit profiling tool, we can see that IndexedDB is the slowest part of our applications, as transactions with the database must be opened and closed. Ideally, we would use something less complex, but other options such as Local Storage did not have enough space for our large files.

IndexedDB also has a size limit, but this is typically not reached except for unusually long files or files with 4 or more CPUs (not exactly sure what the number is here)

Local Storage Our application also makes use of Local Storage, another tool built into most browsers and node-webkit. This is a small and quick to access storage method. We primarily use it to save state between pages, notably display states. One example is the zoom level of the graph, which does not change between loads of the same page. Local Storage is also retained between application sessions. Similarly to our IndexedDB data, if the user chooses to load the same data we still have their state changes saved. If they load a new file Local Storage is cleared.

Overall Application Structure The general structure of our code is similar to most web applications. In the root we have HTML files, which call to Javascript and CSS files, located in assets/js and assets/css respectively. HTML files do not have any Javascript or CSS inside them, but exclusively call to other functions for this. Each page has itâĂŹs own specific Javascript file, and then there are a number of shared files that multiple or all pages use. We have used a number of Javascript libraries. (List them? Point to our Git? Mer?)

Primary Javascript/CSS files One of the primary Javascript files weâĂŹve worked with and changed is gantt-chart-d3.js. This file is the logic for all of the graphs. We have added a ton of functionality to the original file, including a system to case on what page the graph is on and behave accordingly. For example, graphs on the Compare Page are much smaller than the graph on the Main Page. Additionally, much of the save state code is created and maintained by this file, plus functionality for zooming and panning that did not exist in the base file.

Sidebar.js is a fairly simple script that creates the sidebar for all of the pages, excluding the first page of the app, where the user chooses a file.

The other non-page specific files are mostly borrowed and unedited from Javascript libraries, so for documentation on those you can visit their respective pages online. (Provide these?)

Chapter 3

User Feedback

3.1 General Feedback

3.2 Feedback on Specific Pages

Chapter 4

Challenges

4.1 trace-cmd versioning

As already described, we collect data using a command-line utility called trace-cmd. trace-cmd records various events in the Linux kernel while it runs and then outputs this information into a data file with a particular binary format. trace-cmd also has a "report" option, which takes an existing trace file and generates a human readable report of this record. Using this format as a starting point instead of the raw binary format simplifies parsing. We decided to leverage trace-cmd report instead of wrestling with the binary data ourselves. This allowed us to make progress faster and to avoid working on an already solved problem.

Unfortunately, the format of the file generated by trace-cmd report is dependent on the version of trace-cmd used. For example, the formatting of the "extra info" field of a switch event is liable to change. We use this field to identify preemptions. To be able to reliably parse data and add additional information about preemptions, we need our input data to have a consistent format. This creates a dependency on a particular version of trace-cmd. Our liaisons have been using trace-cmd version 2.2.1, so our parser expects input data to be in the format of 2.2.1.

4.2 Selection of charting tool

We chose to use web technologies because we felt there was a wealth of charting and UI/UX tools that we could use. We spent several weeks experimenting with different charts for the main page. The main page renders a timeline of running tasks, which is essentially a large number of colored

bars. This chart needed to be responsive to zooming and dragging, and to dealing with click events to move to a particular time in the table of events displayed below it.

4.3 Batch loading

Chapter 5

Future Work

5.1 Known bugs

5.2 Extensions

5.3 Scalability

5.4 more user testing - results