Solar Eruptive Events:

Coronal Dimming and a New CubeSat Mission

by

James Paul Mason

B.S., University of California at Santa Cruz, 2009

M.S., University of Colorado at Boulder, 2012

A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

Department of Aerospace Engineering Sciences

2016

This thesis entitled:

Solar Eruptive Events:
Coronal Dimming and a New CubeSat Mission
written by James Paul Mason
has been approved for the Department of Aerospace Engineering Sciences

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Dr. Thomas Wooods

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Prof. Xinlin Li

_____
Prof. Scott Palo

_____
Dr. Amir Caspi

_____
Prof. Jeffrey Forbes

Date _____

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

Mason, James Paul (Ph.D., Aerospace Engineering Sciences)

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Thesis directed by Dr. Thomas Wooods

Often the abstract will be long enough to require more than one page, in which case the macro "\OnePageChapter" should *not* be used.

But this one isn't, so it should.

Dedication

To my late father, who inspired me from an early age to come this far.

Acknowledgements

First and foremost, my deepest thanks to Tom Woods. Through the projects he's introduced me to – in solar physics, in sounding rockets, and in small satellites – I've discovered a career path that excites me and that provides continuous opportunities to learn and contribute. Moreover, he's an excellent role model: dedicated and passionate about his work, patient with everyone without seeming to have to try, and exceptionally reliable. All of the above combined has made my time in graduate school likely to be, upon reflection long from now, one of the highlights of my life. Thank you to my committee for guidance and support, most of whom I've been fortunate to work with closely: Xinlin Li, Scott Palo, Amir Caspi, and Jeff Forbes. Finally, I couldn't have struggled through without the support of my peers, especially Allison Youngblood, whose work ethic inspires me and whom I've been extremely lucky to find. Oh, and my dog, Nessie, who requires three walks a day, has turned out to provide the periods of relaxation away from a screen that have aided in my ability to actually comprehend the work I'm doing.

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Chapter 1

Introduction

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---

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<center>**Chapter 2**</center>

<center>**Relevant Background**</center>

The objective of this fake thesis document is to demonstrate a multitude of LATEX features as well as features specific to the thesis class. We start by giving one short formula, and one big hairy multi-line formula (one of the non-dimensional Navier-Stokes equations):

$$A = \pi r^2 \tag{2.1}$$

$$
\begin{aligned}
\rho \left[\frac{DV_r}{Dt} - M\epsilon^2 \frac{V_\theta^2}{r} \right] \;=\; & -\frac{\delta^2}{\gamma\,M} \frac{\partial P}{\partial r} + \frac{M\,\delta^2}{Re} \left\{ 2\frac{\partial}{\partial r}\left[\mu\left(\frac{\partial V_r}{\partial r} - \frac{1}{3}\nabla\cdot\overline{\mathbf{V}} \right) \right] \right. \\
& + \frac{1}{r}\frac{\partial}{\partial\theta}\left[\mu\left(\frac{1}{r}\frac{\partial V_r}{\partial\theta} + \epsilon\frac{\partial V_\theta}{\partial r} - \epsilon\frac{V_\theta}{r} \right) \right] \\
& + \frac{\partial}{\partial z}\left[\mu\left(\frac{1}{\delta^2}\frac{\partial V_r}{\partial z} + \frac{\partial V_z}{\partial r} \right) \right] \\
& \left. + 2\frac{\mu}{r}\left[\frac{\partial V_r}{\partial r} - \frac{\epsilon}{r}\frac{\partial V_\theta}{\partial\theta} - \frac{V_r}{r} \right] \right\},
\end{aligned}
\tag{2.2}
$$

2.1 Explanation of equations

The latter equation is non-dimensionalized using the following definitions:

$$r = \frac{r'}{R'}, \quad z = \frac{z'}{L'}, \quad t = \frac{t'}{t'_a}, \quad \kappa = \frac{\kappa'}{\kappa'_0}, \quad \mu = \frac{\mu'}{\mu'_0}, \quad C_V = \frac{C'_V}{C'_{V0}},$$

where P'_0 is the initial static pressure in the cylinder, and ρ'_0 and T'_0 are the density and temperature of the fluid being injected from the sidewall.

Here is an example of using the macros `\singlespacing` and `\doublespacing`:

Figure 2.1: A triangular pyramid may be cut up as shown, to yield one top pyramid (with one-eighth the volume of the full pyramid), three bottom corner pyramids (which, when joined, are congruent to the top pyramid), three prisms along the bottom edges (the area of whose bottom faces total $B/2$) and the large central prism (volume $= (B/4)(h/2) = Bh/8$). The image, from PDF file "pyr.pdf", was read in using the \includegraphics command, from the graphicx package.
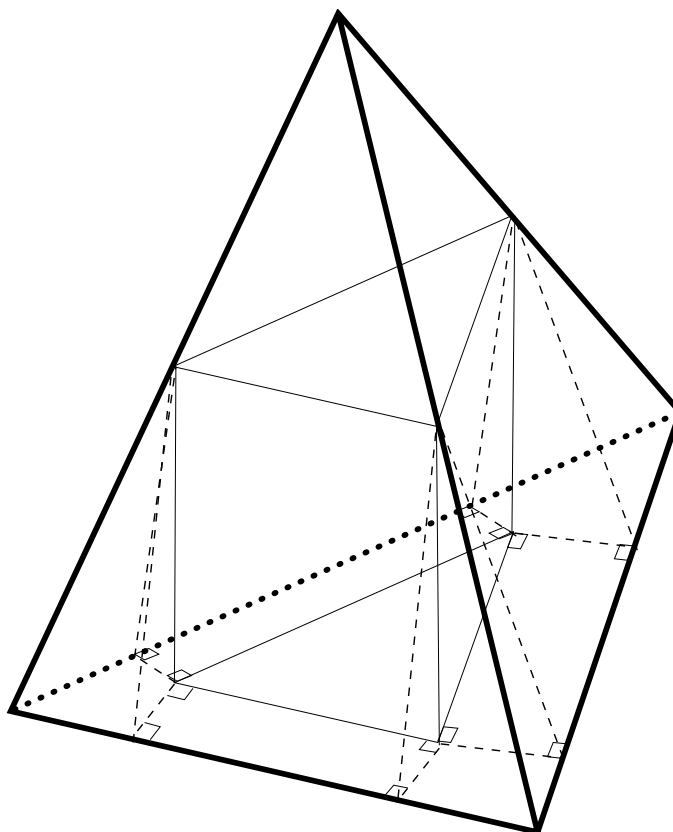
This paragraph was preceded by the command `\singlespacing`. See the Specifications of the Grad School for instructions about when single spacing is appropriate in a thesis.

And now, here is an example of using the macros `\begin{singlespace}` and `\end{singlespace}`;

another way to get single-spacing.

Two cases are studied in the present work which differ only in the boundary conditions. Each different boundary condition model a different source of instability. The boundary of the first case consists of a steady, axisymmetric sidewall radial velocity boundary and a time-dependent, non-axisymmetric endwall axial velocity boundary. The second case is studied with a fixed impermeable axial velocity along the endwall and a combination axisymmetric steady and non-axisymmetric unsteady radial velocity along the sidewall.

Usually you want to use a table produced by some other software, such as Excel, rather than

try to do it using LATEXmacros. If the table is saved/printed to a PDF file, then it can be displayed

using the `\includegraphics` macro inside a `table` environment:

Some of the boundary conditions are:

$$z = 0; \quad V_z = \begin{cases} 0, & t \leq 0 \\ \\ \widetilde{F}_{zw}(r, \theta, t), & t > 0 \end{cases} \tag{2.3}$$

$$z = 0; \quad V_\theta = V_r = 0 \tag{2.4}$$

$$r = 0; \quad P, \rho, T, V_r, V_\theta, V_z \text{ finite,} \tag{2.5}$$

$$r = 1; \quad V_r = F_{rws}(z), \tag{2.6}$$

$$r = 1; \quad V_z = V_\theta = 0, \tag{2.7}$$

and solutions must be periodic in θ.

If you don't believe this stuff, check out Mulick[10] and Baylor[1].

2.2   Yet another section

2.2.1   Just meaningless text to test lines per page

According to the Grad School specs. there should be 24–27 lines of print per page of a thesis.

This should be true whether the font size is 10, 11, or 12. Count them up; does this document

Table 2.1:   This table wasn't constructed with LaTeX commands, but resides in PDF file (`tableD.pdf`) created by some other software.

n	n^2	n^3	n^4	n^7	n^{13}
2	4	8	16	128	8192
3	9	27	81	2187	1594323
4	16	64	256	16384	67108864
5	25	125	625	78125	1220703125
6	36	216	1296	279936	13060694016
7	49	343	2401	823543	96889010407

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What is it? This is a labelled paragraph. The heading of the paragraph is emphasized. This is a labelled paragraph. The heading of the paragraph is emphasized.

2.2.2 This is a subsection

This is a subsection. Filler filler filler filler filler filler filler filler. Filler filler filler filler filler filler filler filler.

2.2.3 This is another subsection

This is another subsection. Filler filler filler filler filler filler filler filler. Filler filler filler filler filler filler filler filler.

This is paragraph number 2. It used a `\paragraph{}` header, which are always inlined (with extra space) and boldfaced.

This is the third paragraph of the subsection. Filler filler filler filler filler filler filler filler. Filler filler filler filler filler filler filler filler.

2.2.3.1 This is a subsubsection (1)

This is the first paragraph of the subsubsection. Whether it is numbered or inlined depends on the option selected at the beginning of the thesis.

By default, a `\subsubsection` heading is numbered and set off on a separate line, left-justified.

However. Using the `inlineh4` option, subsubsection headers are inlined. And using the

`nonumh4` option suppresses numbering of the subsubsections. Together they make subsubsection headings just the same as paragraph headings.

2.2.3.2   This is another subsubsection (2)

Once again, whether its heading is numbered and/or inlined depends on the class options chosen at the start.

There is no "subsubsubsection" entity, and "subparagraph" gets no special treatment in **thesis** class.

2.3   The End

Finally, this is the end. The bibliography starts on the next page. Note how the `\hyperref` package (mentioned in chapter **??**) also makes hyperlinks from references (e.g., Mulick[10]) to entries in the bibliography.

Chapter 3

Mechanisms of Coronal Dimming

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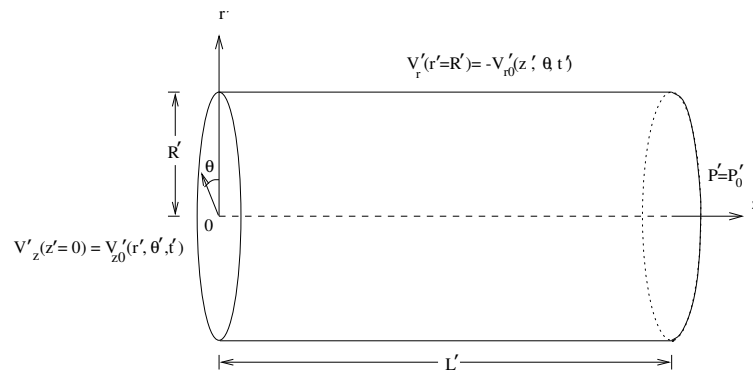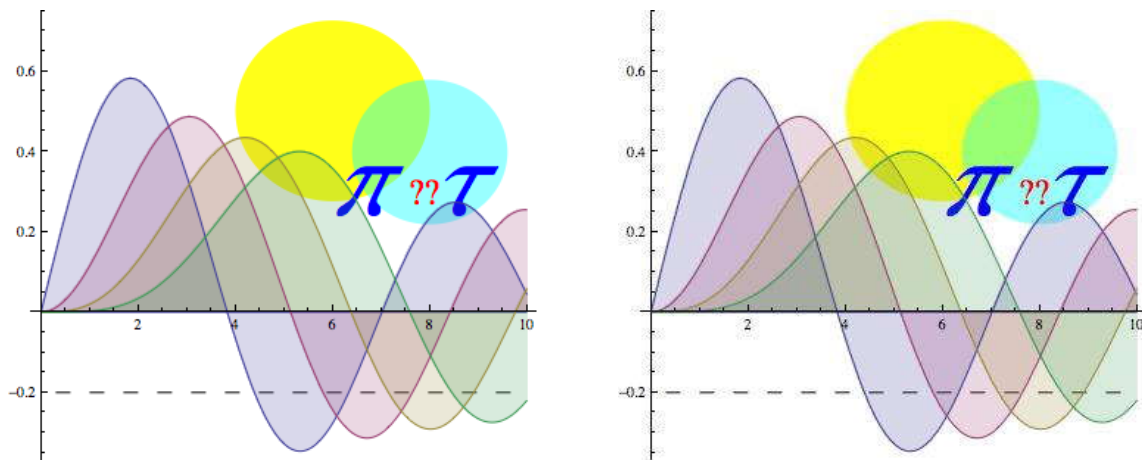

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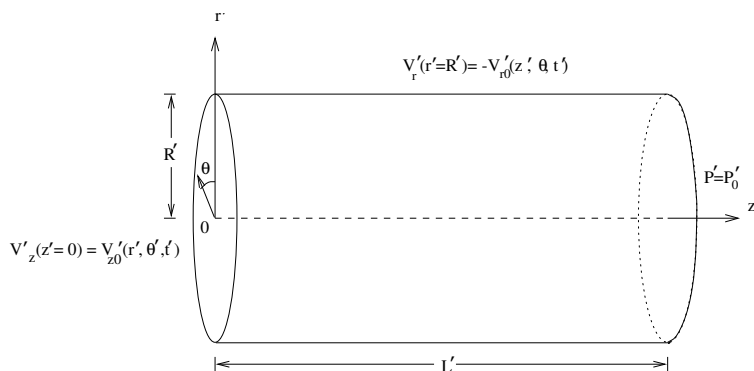

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Chapter 5

Semi-Statistical Study of Coronal Dimming

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$$V'_r(r'=R')= -V'_{r0}(z', \theta, t')$$

$$P'=P'_0$$

$$V'_z(z'=0) = V'_{z0}(r', \theta', t')$$

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*kVAr means reactive power.
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Chapter 6

Overview of MinXSS Solar CubeSat

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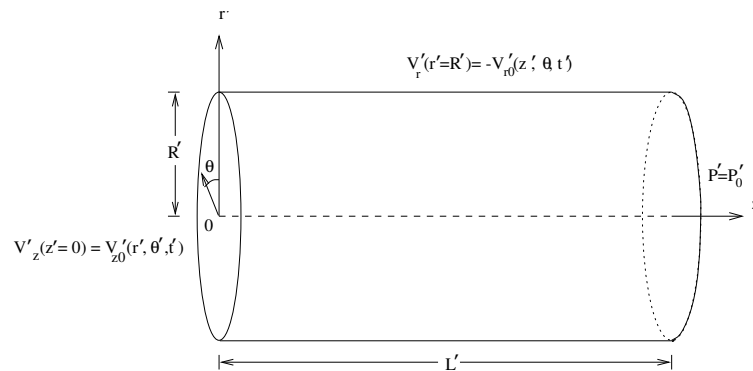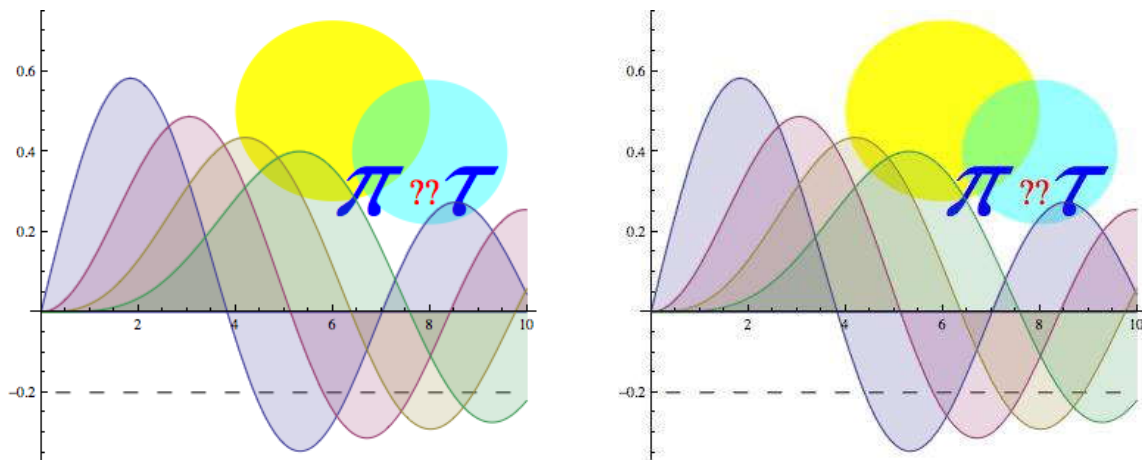

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Chapter 7

Thermal Balance Analysis for a CubeSat

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Chapter 8

Summary and Future Work

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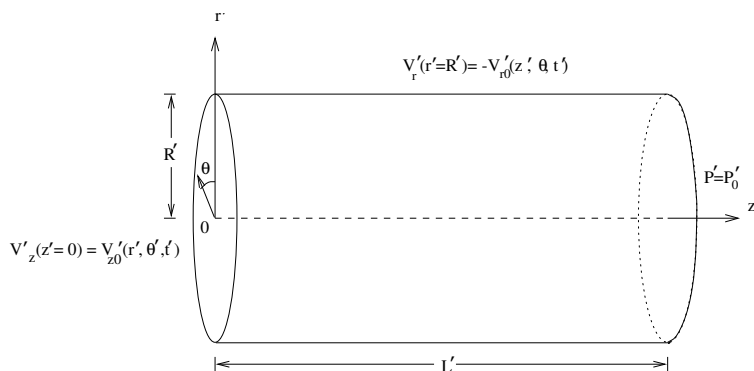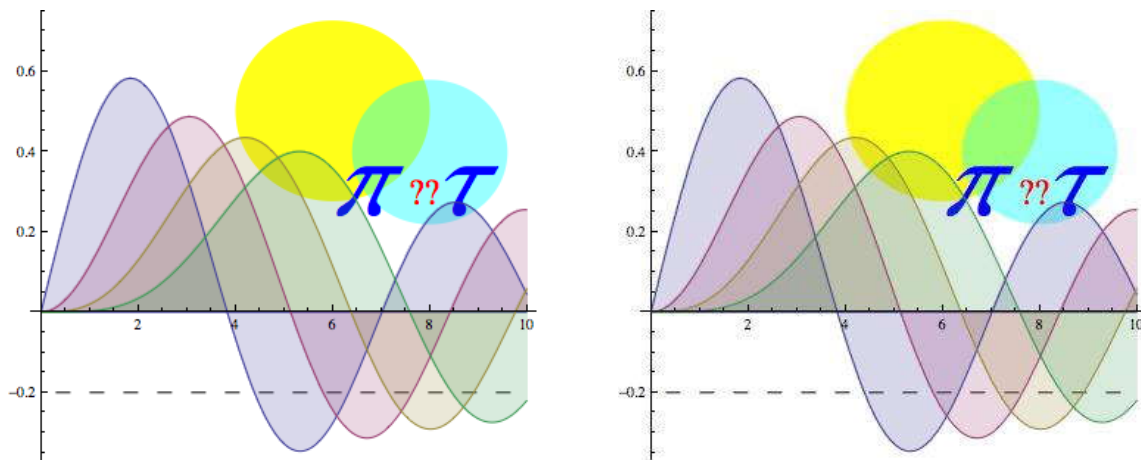

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Appendix A

Coronal Dimming Event List and Ancillary Data

About appendices: Each appendix follow the same page-numbering rules as a regular chapter; the first page of a (multi-page) appendix is not numbered. By the way, the following are supposedly authentic answers to English GCSE exams!

(1) The Greeks were a highly sculptured people, and without them we wouldnt have history. The Greeks also had myths. A myth is a female moth.

(2) Actually, Homer was not written by Homer but by another man of that name.

(3) Socrates was a famous Greek teacher who went around giving people advice. They killed him. Socrates died from an overdose of wedlock. After his death, his career suffered a dramatic decline.

(4) Julius Caesar extinguished himself on the battlefields of Gaul. The Ides of March murdered him because they thought he was going to be made king. Dying, he gasped out: Tee hee, Brutus.

(5) Nero was a cruel tyranny who would torture his subjects by playing the fiddle to them.

(6) In midevil times most people were alliterate. The greatest writer of the futile ages was Chaucer, who wrote many poems and verses and also wrote literature.

(7) Another story was William Tell, who shot an arrow through an apple while standing on his sons head.

(8) Writing at the same time as Shakespeare was Miguel Cervantes. He wrote Donkey Hote. The next great author was John Milton. Milton wrote Paradise Lost. Then his wife died and he wrote Paradise Regained.

(9) During the Renaissance America began. Christopher Columbus was a great navigator who discovered America while cursing about the Atlantic. His ships were called the Nina, the Pinta, and the Santa Fe.

(10) Gravity was invented by Issac Walton. It is chiefly noticeable in the autumn when the apples are falling off the trees.

(11) Johann Bach wrote a great many musical compositions and had a large number of children. In between he practiced on an old spinster which he kept up in his attic. Bach died from 1750 to the present. Bach was the most famous composer in the world and so was Handel. Handel was half German half Italian and half English. He was very large.

(12) Soon the Constitution of the United States was adopted to secure domestic hostility. Under the constitution the people enjoyed the right to keep bare arms.

(13) The sun never set on the British Empire because the British Empire is In the East and the sun sets in the West.

(14) Louis Pasteur discovered a cure for rabbis. Charles Darwin was a naturalist who wrote the Organ of the Species. Madman Curie discovered radio. And Karl Marx became one of the Marx brothers.

Appendix B

MinXSS CubeSat Mass/Power Tables

(Data, Stardate 1403827)   (A one-page chapter — page must be numbered!) Throughout the ages, from Keats to Giorchamo, poets have composed "odes" to individuals who have had a profound effect upon their lives. In keeping with that tradition I have written my next poem . . . in honor of my cat. I call it. . . Ode. . . to Spot. (Shot of Geordi and Worf in audience, looking mystified at each other.)

> Felus cattus, is your taxonomic nomenclature
> an endothermic quadruped, carnivorous by nature?
> Your visual, olfactory, and auditory senses
> contribute to your hunting skills, and natural defenses.
> I find myself intrigued by your sub-vocal oscillations,
> a singular development of cat communications
> that obviates your basic hedonistic predilection
> for a rhythmic stroking of your fur to demonstrate affection.
> A tail is quite essential for your acrobatic talents;
> you would not be so agile if you lacked its counterbalance.
> And when not being utilized to aid in locomotion,
> It often serves to illustrate the state of your emotion.

(Commander Riker begins to applaud, until a glance from Counselor Troi brings him to a halt.)

Commander Riker, you have anticipated my denouement. However, the sentiment is appreciated. I will continue.

> O Spot, the complex levels of behavior you display
> connote a fairly well-developed cognitive array.
> And though you are not sentient, Spot, and do not comprehend
> I nonetheless consider you a true and valued friend.

Appendix C

MinXSS Thermal Model Parameter Tables

(Data, Stardate 1403827)   (A one-page chapter — page must be numbered!) Throughout

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