

Optimal Engine Selection and Trajectory Optimization using Genetic Algorithms for conceptual design Optimization of Reusable Space Launch Vehicles

Steven Cory Wyatt Steele

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements of the degree of

Master of Science
in
Mechanical Engineering

Walter F. O'Brien, Chair
Michael von Spakovsky
Eugene Cliff

February 19, 2015
Blacksburg, Virginia

Keywords: Trajectory Optimization, Engine Selection, Reusable Launch Vehicle (RLV), Two Stage to Orbit (TSTO)

For Figure 1 on page 1. Note: This contact was initially made by phone.

 Reply  Reply All  Forward



Wed 3/4/2015 2:16 PM

Ashley Russ <ashley.russ@sei.aero>

Copyright Permission, SpaceWorks Enterprises, Inc.

To scwsteel@vt.edu

Cc John E. Bradford

 You replied to this message on 3/5/2015 8:14 AM.

Hi Steven,

Thank you for reaching out to us. You are more than welcome to use the QuickSat image (Figure 1) from the AIAA paper 2004-59-50. Please credit "SpaceWorks Enterprises, Inc." Let me know if there is anything else we can assist you with.

Thanks!

Ashley

--

Ashley Russ

Director of Human Resources

SpaceWorks Enterprises, Inc. (SEI)

1040 Crown Pointe Pkwy, Suite 950 | Atlanta, GA 30338

Office: +1.770.379.8008

Fax: +1.770.379.8001

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For Figure 5 on pg 14

 Reply  Reply All  Forward



Wed 3/4/2015 11:22 AM

Heather Brennan <HeatherB@aiaa.org>

RE: Grad student requesting permission for image use from AIAA papers

To: Steven Steele

 You replied to this message on 3/4/2015 11:28 AM.

Steve,

The first paper, 2004-5950, is a work of the U.S. Government, which means that you need to cite the original work but you don't need to acknowledge that you have permission to reprint, as the paper is in the public domain in the United States.

AIAA grants permission for you to reprint Figure 1 from Optimal Ascent of a Horus/Sanger Type Space Vehicle, by Sachs and Drexler, AIAA paper 88-4298. Please include appropriate acknowledgment in the caption and reference citation as described in the permission details of your initial request.

Heather

From: Steven Steele [<mailto:scwsteel@vt.edu>]

Sent: Wednesday, March 04, 2015 11:09 AM

To: **Heather** Brennan

Subject: Grad student requesting permission for image use from AIAA papers

Heather,

Thank you so much for your help. If is not too much trouble, I have two more images to ask about.

1). This image is Figure 1 from AIAA 2004-5950. ***Quicksat: A Two-Stage to***

For Figure 6 on page 15 and Figure 16 on page 38



Fri 2/6/2015 4:51 PM

Joachim Kurzke <kurzke@gasturb.de>

RE: Graduate student requesting permission to cite GasTurb.

To: 'Steven Steele'

No problem – use the pictures and have success. Just give a reference to GasTurb

Best wishes

Joachim Kurzke

From: Steven Steele [<mailto:scwsteel@vt.edu>]

Sent: Freitag, 6. Februar 2015 20:15

To: Joachim Kurzke

Subject: Fwd: Graduate student requesting permission to cite GasTurb.

I have attached the picture that I wish to use in my thesis.

----- Forwarded message -----

From: Steven Steele <scwsteel@vt.edu>

Date: Fri, Feb 6, 2015 at 2:10 PM

Subject: Graduate student requesting permission to cite GasTurb.

To: kurzke@gasturb.de

↑ Next ↑ Last

Hello Dr. Kurzke,

My name is Steven Steele and I am a graduate student studying with Walter O'Brien at Virginia Tech.

I am asking your permission to reproduce two turbine engine pictures that are from GasTurb 11 in my thesis and to also cite the user manual for GasTurb 11.

Please let me know.

 See more about Joachim Kurzke.



Figure 7 on page 18.



Wed 3/4/2015 11:39 AM

Heather Brennan <HeatherB@aiaa.org>

RE: Grad student requesting permission for image use from AIAA papers

To Steven Steele

i You replied to this message on 3/4/2015 4:12 PM.

I apologize; in my haste to respond quickly I did not see the second request.

AIAA grants permission for you to use an adapted version of Figure 10 from AIAA paper 90-1933 in your thesis, as described below. Appropriate credit must be given in the figure caption (e.g., "Adapted from [paper title and authors]; reprinted by permission of the American Institute of Aeronautics and Astronautics, Inc."). Note that the original source should be cited in full in the reference list.

Heather A. Brennan
Director, Publications

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AIAA is celebrating [Engineers Week](#), February 22-28. Together we are Engineering New Horizons!



Shaping the Future of Aerospace

i See more about Heather Brennan.



For Figure 8 on page 19



Thu 3/5/2015 4:43 PM

Ashley Russ <ashleyruss88@gmail.com>

Copyright Permission 2 - SpaceWorks Enterprises, Inc.

To scwsteel@vt.edu

Hi Steven,

Yes, you can use [Figure 2 from the AIAA paper cited as: Olds, J.R. and J.E. Bradford, *SCCREAM: A Conceptual Rocket-Based Combined-Cycle Engine Performance Analysis Tool*. Journal of Propulsion and Power, 2001. 17\(2\): p. 333-339.. Please credit "SpaceWorks Enterprises, Inc."](#) Let me know if there is anything else we can assist you with.

Thanks!

Ashley

--

Ashley Russ

Director of Human Resources

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1040 Crown Pointe Pkwy, Suite 950 | Atlanta, GA 30338

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Fax: +1.770.379.8001

Email: ashley.russ@sei.aero | www.sei.aero

Additional information:

Hi Steven,

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Thanks!

Ashley

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Ashley Russ

Director of Human Resources

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Office: +1.770.379.8008

Fax: +1.770.379.8001

Email: ashley.russ@sei.aero | www.sei.aero

Hi Ashley,

Could get you to ask something of Dr. Olds or Dr. Bradford? I wanted permission to use Figure 2 from the AIAA paper cited as: Olds, J.R. and J.E. Bradford, *SCCREAM: A Conceptual Rocket-Based Combined-Cycle Engine Performance Analysis Tool*. Journal of Propulsion and Power, 2001. **17**(2): p. 333-339.

I tried getting permission from AIAA but they said that the copyrights for the image were held on to by the authors who I know both work at Spaceworks.

I hope to hear back from you soon. Thank you.

Sincerely,

Steven C.W. Steele

Masters Candidate

Center for Turbomachinery & Propulsion Research

Mechanical Engineering Department

Virginia Tech

For Figure 9 on page 20 and Figure 14 on page 34



Mon 2/9/2015 7:01 PM

Francesco Cremaschi <francesco.cremaschi@astos.de>

Re: Thesis of Steven Steele

To: O'Brien, Walter

Cc: Steele, Steven

Dear Walt,

thank you for the summary.

You have our permission to use the material mentioned and thank you for the confidence in our software.

I would appreciate the thesis or an extract of it in order to evaluate the quality of the work produced.

We are also active in the design field and we have linked a third-party tool RPA (Rocket Propulsion Analysis) in the latest version of **ASTOS**.

Best regards

Francesco

Francesco Cremaschi

Sales Manager

Astos Solutions GmbH
Meitnerstrasse 8
70563 Stuttgart
Germany

Phone: +49 711 892633 - 14
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Astos Solutions GmbH
Grund 1
78089 Unterkirnach
Germany

Amtsgericht Freiburg i.Br., HRB 603117
Management: Dipl.-Ing. Andreas Wianand

 See more about Francesco Cremaschi.



Full email conversation below:

Dear Walt,

thank you for the summary.

You have our permission to use the material mentioned and thank you for the confidence in our software.

I would appreciate the thesis or an extract of it in order to evaluate the quality of the work produced.

We are also active in the design field and we have linked a third-party tool RPA (Rocket Propulsion Analysis) in the latest version of ASTOS.

Best regards

Francesco

Francesco Cremaschi

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<http://www.astos.de>

Email: francesco.cremaschi@astos.de

On 09-Feb-15 22:33, O'Brien, Walter wrote:

Francesco; My student, Steven Steele, has completed his MS thesis, and will soon defend it to his Committee.

In the thesis, he cited data from ASTOS, and he wishes to use pictures from the ASTOS Model Library.

Following is Steven's summary of what he did, and the use he made of ASTOS material:

In this thesis a new code named Steele-Flight was developed to perform simultaneous optimal engine selection and trajectory optimization. However, each of these abilities had to be verified individually in the thesis.

In order to validate Steele-Flight's capability as a trajectory optimizer, it is compared to ASTOS. The test was a comparison, in which both codes ran the advanced launcher example provided with the academic license for ASTOS 7.2.0. Thus, the ASTOS model library manual and the Advanced launcher manual were both cited. All the same model parameters from the Advanced launcher example were used, however, the trajectory was modified into a 2D flight along the equator. Constraints and orbits

used to define the mission were mentioned and the data output in the form of graphs are shown as MATLAB generated plots.

In addition to this, two pictures from the ASTOS Model Library Manual were used to explain trajectory coordinate systems(Fig 13.4) and oblate planets (Fig 9.1).

Furthermore, when verifying Steele-Flight's ability to choose optimal engine configurations, the same aerodynamic library, weight estimations and tank volume estimations for the Saenger that were used in the Advanced Launcher example were used due to lack of availability of other models.

All use of ASTOS material is cited.

We request your permission to use the listed materials in the thesis.

Thanks,

Walt

Walter F. O'Brien

J. Bernard Jones Professor

Mechanical Engineering Department

Randolph Hall Room 109, Mail Code 0710

Virginia Tech

Blacksburg, VA 24061

Office Telephone 540-231-9104

Cell 540-239-1632

For Figure 17 on page 39



Wed 3/4/2015 11:02 AM

Heather Brennan <HeatherB@aiaa.org>

RE: Grad student needing permission to use images from AIAA paper in his thesis

To Steven Steele

Dear Steve,

Thanks for sending the details of your request. There are no third-party claims to the figure you have referenced, and so AIAA grants permission for you to use an adapted version of Figure 4 from AIAA paper 93-5161 in your thesis, as described below. Appropriate credit must be given in the figure caption (e.g., "Adapted from [paper title and authors]; reprinted by permission of the American Institute of Aeronautics and Astronautics, Inc."). Note that the original source should be cited in full in the reference list.

I have included a link here to AIAA's rights and permissions page, which has additional information that may be helpful to you if you have reprint requests in the future:

<https://www.aiaa.org/rightsandpermissions/>

If I can be of further assistance, please let me know.

Sincerely,

Heather A. Brennan
Director, Publications

American Institute of Aeronautics and Astronautics www.aiaa.org
1801 Alexander Bell Drive, Suite 500, Reston, VA 20191-4344
heatherb@aiaa.org 703.264.7568 (direct)



Follow us on Twitter [@aiaa](https://twitter.com/aiaa)



See more about Heather Brennan.



Full conversation:

Dear Steve,

Thanks for sending the details of your request. There are no third-party claims to the figure you have referenced, and so AIAA grants permission for you to use an adapted version of Figure 4 from AIAA

paper 93-5161 in your thesis, as described below. Appropriate credit must be given in the figure caption (e.g., “Adapted from [paper title and authors]; reprinted by permission of the American Institute of Aeronautics and Astronautics, Inc.”). Note that the original source should be cited in full in the reference list.

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<https://www.aiaa.org/rightsandpermissions/>

If I can be of further assistance, please let me know.

Sincerely,

Heather A. Brennan

Director, Publications

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AIAA is celebrating [Engineers Week](#), February 22-28. Together we are Engineering New Horizons!



From: Steven Steele [<mailto:scwsteel@vt.edu>]

Sent: Wednesday, March 04, 2015 10:40 AM

To: Heather Brennan

Subject: Grad student needing permission to use images from AIAA paper in his thesis

Hello Heather,

My name is Steven Steele and I spoke to you at 10:25am today about permissions to use pictures taken from AIAA papers in my Masters thesis.

The images that I want to use are:

1). Figure 4 from AIAA-93-5161. SANGER - The Reference Concept of the German Hypersonics Technology Program. S. Weingartner. DOI: 10.2514/6.1993-5161

I have modified this picture to suit my needs for illustration. I have attached a png form that shows how the picture was modified so you can compare it with the image in the original document and tell me if it is alright.

2). Figure 10 from AIAA 90-1933. Advanced Two-Stage Vehicle Concepts (SANGER). D. Koelle. DOI: 10.2514/6.1990-1933.

The only modification that I made to this figure is the fact that I cropped out the bottom image in this figure.

Thank you very much for taking the time to help me and I look forward to hearing back from you today!

Sincerely,

Steven C.W. Steele

Masters Candidate

Center for Turbomachinery & Propulsion Research

Mechanical Engineering Department

Virginia Tech
