**Coordinate Transformations for Unsteady Frames**

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Indented abstract here!

# Nomenclature

= tangent vector of Frenet frame

= binormal vector of Frenet frame

= normal vector of Frenet frame

= position vector of Micro Aerial Vehicle (MAV)

= velocity vector of MAV

= acceleration vector of MAV

t = time of measurement

# Introduction

T

HE Frenet frame is a useful set of coordinates centered on a particle. The basis vectors describe the motion of the particle, showing the instantaneous direction of motion and the instatntaneous radius of curvature of the path. (SOURCE)This project focuses on the use of the Frenet frame on the paths of a unmanned aerial vehicle (UAV) mothership (MS) and Micro Aerial Vehicles (MAVs) deployed by the MS to act as sensory equipment. (SOURCE). The MAV motion with respect to the MS are a known quantity. Sensory data is then relayed from the MS to a ground station (GS), so coordinate transformations must be applied to obtain the MAV motion with respect to the GS.

The Frenet frame for a particle on a path is obtained by defining the tanget vector as

One can see that the tangent vector is solely in the direction of motion. The binormal vector is defined as

Thus, the binormal vector is normal to both the direction of motion and the particle acceleration. WHAT ABOUT WHEN they are collinear?? Finally, the normal vector is found to complete the three-dimensional coordinate frame by

This normal vector is normal to the curve of the path, and so it is useful to find the normal component of a particle’s acceleration.

To find the Frenet basis vectors for a given instant, the first and second derivatives of the position vector must be known. An analytic expression for the position vector will easily yield an analytic expression for these derivatives, but it is not the case when only time-stamped position data profided. In the latter case, one can forward-differentiate the *n*th data point by

This method will reduce the amount of data points by one for each derivative taken. For example, given five position vectors in time, one will end up with four velocity vectors and three acceleration vectors.

# Simulation of Known Analytical Path

Consider the path of the MS, with respect to the GS and expressed in a Cartesian frame:

And the path of an MAV in the MS Frenet frame:

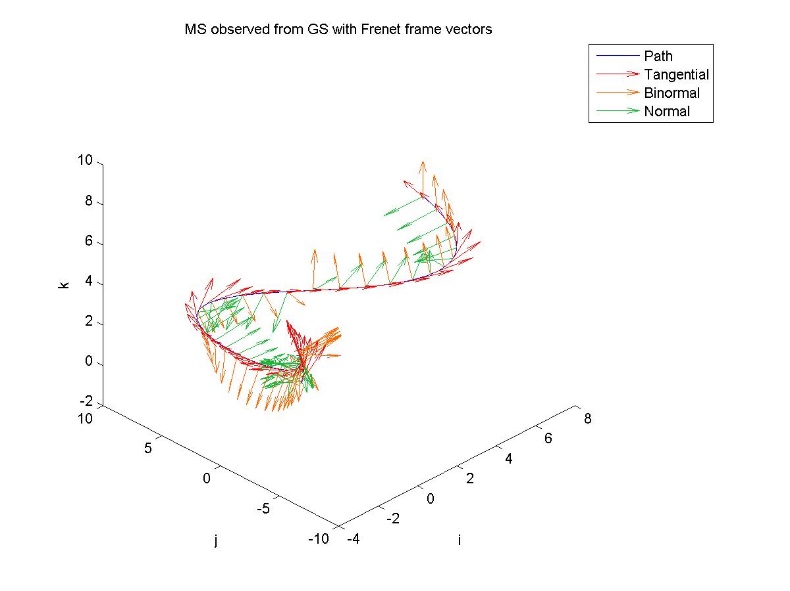
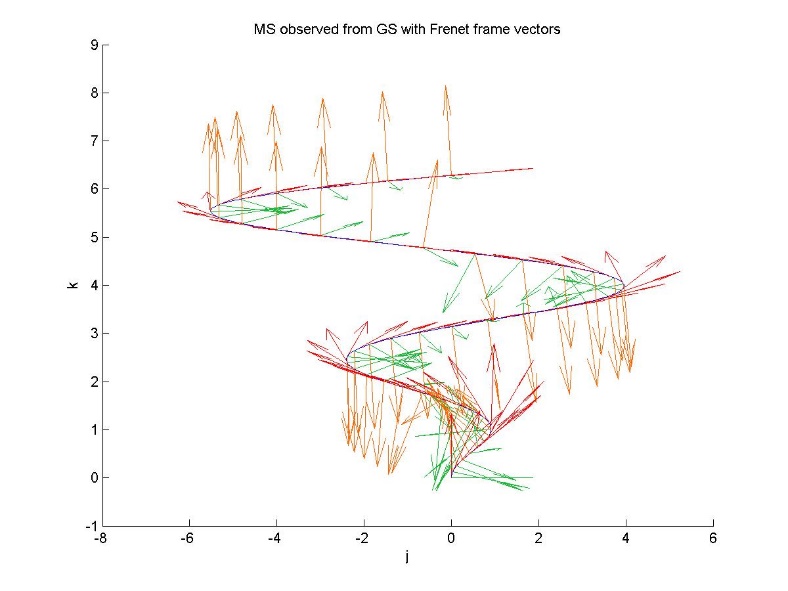
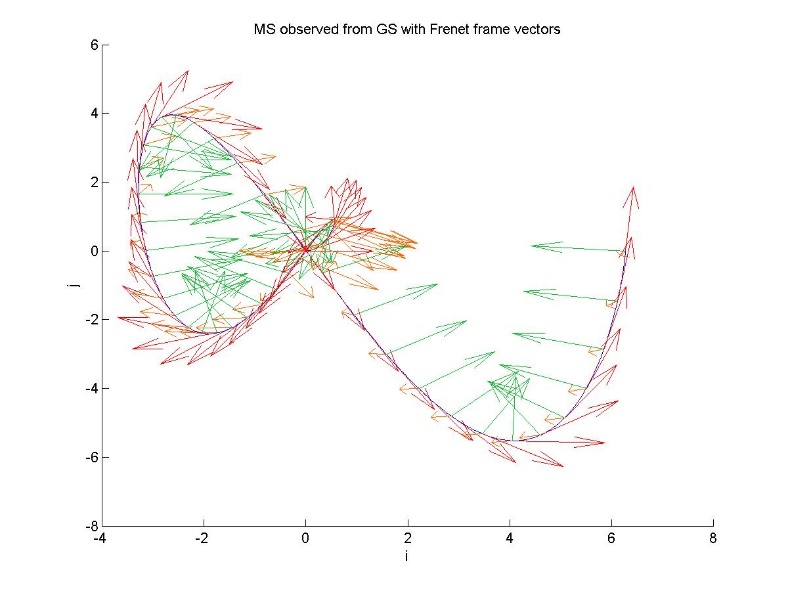


Figure :Mothership position wrt groundstation, with Frenet frame vectors

asdf

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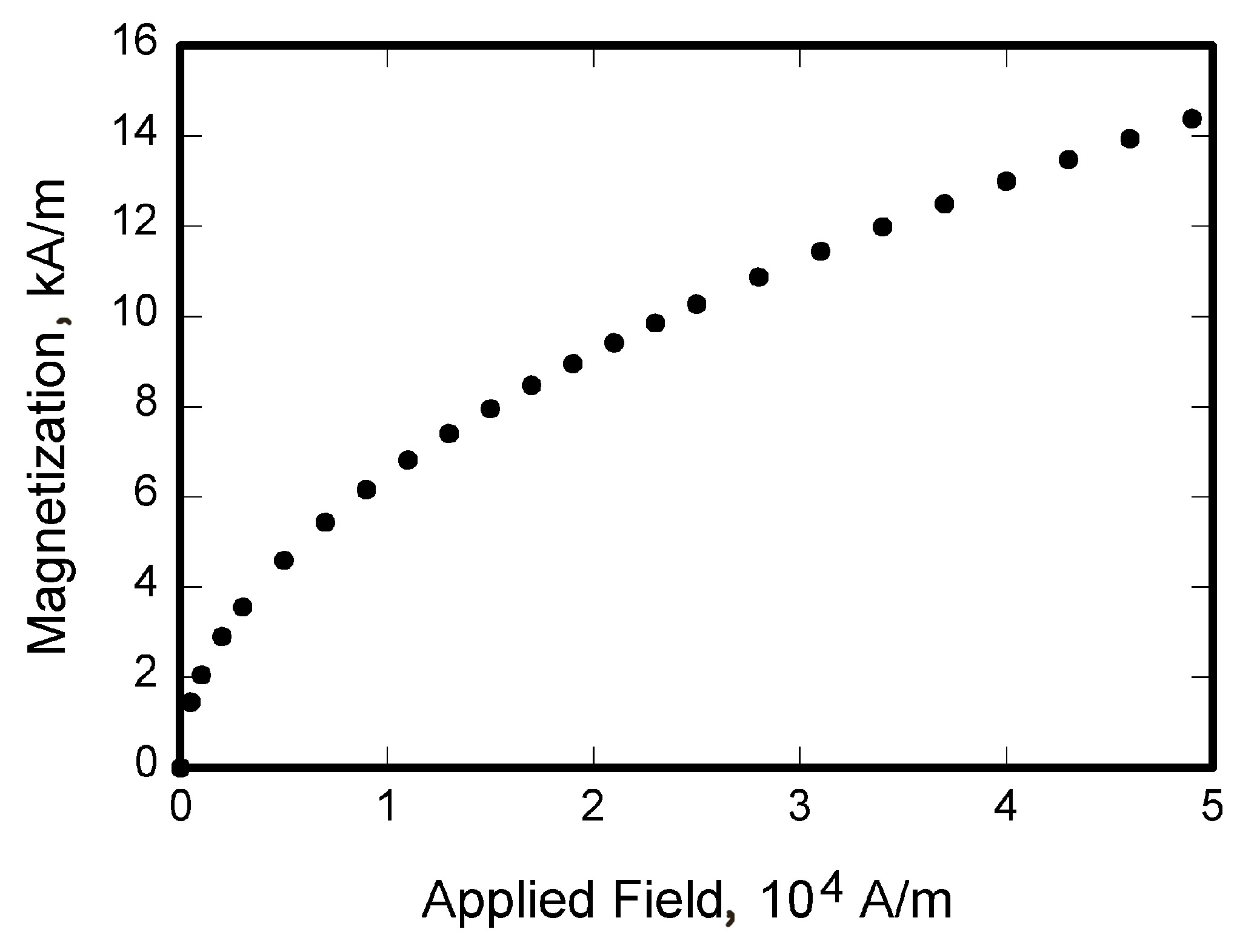


Figure 1. Magnetization as a function of applied field. *Figure captions should be bold and justified, with a period and a single tab (no hyphen or other character) between the figure number and the figure description.*

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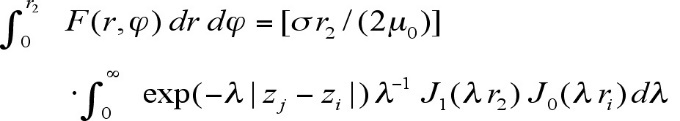
Equations are centered and numbered consecutively, with equation numbers in parentheses flush right, as in Eq. (1). Insert a blank line on either side of the equation. First use the equation editor to create the equation. If you are using Microsoft Word, use either the Microsoft Equation Editor or the MathType add-on (<http://www.mathtype.com>) for equations in your paper, use the function (Insert>Object>Create New>Microsoft Equation *or* MathType Equation) to insert it into the document. Please note that “Float over text” should *not* be selected. To insert the equation into the document:

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 (1)

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Use a zero before decimal points: “0.25,” not “.25.” Use “cm2,” not “cc.” Indicate sample dimensions as “0.1 cm x 0.2 cm,” not “0.1 x 0.2 cm2.” The preferred abbreviation for “seconds” is “s,” not “sec.” Do not mix complete spellings and abbreviations of units: use “Wb/m2” or “webers per square meter,” not “webers/m2.” When expressing a range of values, write “7 to 9” or “7-9,” not “7~9.”

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The word “data” is plural, not singular (i.e., “data are,” not “data is”). The subscript for the permeability of vacuum µ0 is zero, not a lowercase letter “o.” The term for residual magnetization is “remanence”; the adjective is “remanent”; do not write “remnance” or “remnant.” The word “micrometer” is preferred over “micron” when spelling out this unit of measure. A graph within a graph is an “inset,” not an “insert.” The word “alternatively” is preferred to the word “alternately” (unless you really mean something that alternates). Use the word “whereas” instead of “while” (unless you are referring to simultaneous events). Do not use the word “essentially” to mean “approximately” or “effectively.” Do not use the word “issue” as a euphemism for “problem.” When compositions are not specified, separate chemical symbols by en-dashes; for example, “NiMn” indicates the intermetallic compound Ni0.5Mn0.5 whereas “Ni–Mn” indicates an alloy of some composition NixMn1-x.

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A conclusion section is not required, though it is preferred. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. *Note that the conclusion section is the last section of the paper that should be numbered. The appendix (if present), acknowledgment, and references should be listed without numbers.*

# Appendix

An appendix, if needed, should appear before the acknowledgements.

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*Periodicals*

1Vatistas, G. H., Lin, S., and Kwok, C. K., “Reverse Flow Radius in Vortex Chambers,” *AIAA Journal*, Vol. 24, No. 11, 1986, pp. 1872, 1873.

2Dornheim, M. A., “Planetary Flight Surge Faces Budget Realities,” *Aviation Week and Space Technology*, Vol. 145, No. 24, 9 Dec. 1996, pp. 44-46.

3Terster, W., “NASA Considers Switch to Delta 2,” *Space News*, Vol. 8, No. 2, 13-19 Jan. 1997, pp., 1, 18.

All of the preceding information is required. The journal issue number (“No. 11” in Ref. 1) is preferred, but the month (Nov.) can be substituted if the issue number is not available. Use the complete date for daily and weekly publications. Transactions follow the same style as other journals; if punctuation is necessary, use a colon to separate the transactions title from the journal title.

*Books*

4Peyret, R., and Taylor, T. D., *Computational Methods in Fluid Flow*, 2nd ed., Springer-Verlag, New York, 1983, Chaps. 7, 14.

5Oates, G. C. (ed.), *Aerothermodynamics of Gas Turbine and Rocket Propulsion*, AIAA Education Series, AIAA, New York, 1984, pp. 19, 136.

6Volpe, R., “Techniques for Collision Prevention, Impact Stability, and Force Control by Space Manipulators,” *Teleoperation and Robotics in Space*, edited by S. B. Skaar and C. F. Ruoff, Progress in Astronautics and Aeronautics, AIAA, Washington, DC, 1994, pp. 175-212.

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*Proceedings*

7Thompson, C. M., “Spacecraft Thermal Control, Design, and Operation,” *AIAA Guidance, Navigation, and Control Conference*, CP849, Vol. 1, AIAA, Washington, DC, 1989, pp. 103-115

8Chi, Y., (ed.), *Fluid Mechanics Proceedings*, SP-255, NASA, 1993.

9Morris, J. D. “Convective Heat Transfer in Radially Rotating Ducts,” *Proceedings of the Annual Heat Transfer Conference*, edited by B. Corbell, Vol. 1, Inst. Of Mechanical Engineering, New York, 1992, pp. 227-234.

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*Reports, Theses, and Individual Papers*

10Chapman, G. T., and Tobak, M., “Nonlinear Problems in Flight Dynamics,” NASA TM-85940, 1984.

11Steger, J. L., Jr., Nietubicz, C. J., and Heavey, J. E., “A General Curvilinear Grid Generation Program for Projectile Configurations,” U.S. Army Ballistic Research Lab., Rept. ARBRL-MR03142, Aberdeen Proving Ground, MD, Oct. 1981.

12Tseng, K., “Nonlinear Green’s Function Method for Transonic Potential Flow,” Ph.D. Dissertation, Aeronautics and Astronautics Dept., Boston Univ., Cambridge, MA, 1983.

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13Richard, J. C., and Fralick, G. C., “Use of Drag Probe in Supersonic Flow,” *AIAA Meeting Papers on Disc* [CD-ROM], Vol. 1, No. 2, AIAA, Reston, VA, 1996.

14Atkins, C. P., and Scantelbury, J. D., “The Activity Coefficient of Sodium Chloride in a Simulated Pore Solution Environment,” *Journal of Corrosion Science and Engineering* [online journal], Vol. 1, No. 1, Paper 2, URL: <http://www.cp/umist.ac.uk/JCSE/vol1/vol1.html> [cited 13 April 1998].

15Vickers, A., “10-110 mm/hr Hypodermic Gravity Design A,” *Rainfall Simulation Database* [online database], URL: <http://www.geog.le.ac.uk/bgrg/lab.htm> [cited 15 March 1998].

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*Computer Software*

16TAPP, Thermochemical and Physical Properties, Software Package, Ver. 1.0, E. S. Microware, Hamilton, OH, 1992.

Include a version number and the company name and location of software packages.

*Patents*

Patents appear infrequently. Be sure to include the patent number and date.

17Scherrer, R., Overholster, D., and Watson, K., Lockheed Corp., Burbank, CA, U.S. Patent Application for a “Vehicle,” Docket No. P-01-1532, filed 11 Feb. 1979.

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18Doe, J., “Title of Paper,” Conference Name, Publisher’s name and location (submitted for publication)

19Doe, J., “Title of Paper,” *Name of Journal* (to be published).

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