ARTICLE ELEMENTS

STYLE SOURCES

General Style: *Journal of Directed Energy Style Sheet* based on *American Institute of Physics (AIP) Style Manual, 4e*
Issues not covered by *AIP*: *Chicago Manual of Style* (*CMOS*), 17e

TITLE, AUTHOR(S), AFFILIATION(S)

Title is Boldface: centered, Title Case, Arial Font, 16 pts
Authors all boldface: centered beneath journal title, Times Font, 10 pts, no titles, academic and professional designations with numeral superscript following comma after surname to designate affiliation
Author affiliation: *All italics,* no closing punctuation listing *Department/Laboratory (if applicable), Institution/Corporation line 1, Institution line 2 (if needed), City, State, Mail Code*
Corresponding author: Asterisk superscript following comma after affiliation superscript

Example:

Rare Earth Dopants in Fiber Lasers

Alan B. Author,[1]* Carol D. Author,[2] and Eva F. Author[1]

[1]*Air Force Research Laboratory, Directed Energy Directorate, Kirtland AFB, New Mexico 87117*
[2]*Serco, Inc., Colorado Springs, Colorado 80916*

*Corresponding author: *Alan.author@myemail.com*

ABSTRACT

No section heading, *content set flush left, no indent first paragraph, all italics.* Avoid callouts to figures, tables, and other art. Limit to ~500 words

NOMENCLATURE

Follows the Keywords.
Heading is **boldface Arial Font**, 12pts, centered on the page, not numbered: **Nomenclature**
Contents set as two-column table, Times Font, no borders, abbreviations in left column, definitions in right column

Example

ADS	Active Denial System
ANOVA	analysis of variance
cm	centimeter

KEYWORDS

KEYWORDS: Please include several for indexing purposes. Section title ALL CAPS with colon, all in Times Font.
Each term lower case (except proper nouns), separated by commas, no ending punctuation
Example: KEYWORDS: refraction, predictive avoidance, Laser Clearinghouse, deconfliction

NUMBERED SECTIONS

Headings, Arial Font

H1: boldface, 12 pts, Title Case, centered, numbered with a period after the number

1. Title Case Section

H2 (subheadings): boldface, 11 pts, Sentence case, centered, double-numbered, no punctuation after number

1.2 Sentence case subsection

H3: *boldface italics*, 11 pts, Sentence Case, flush left, no numbering, font size same as body text

H3 can vary, based on information presented, see examples of other headings, appendix B

Body of Article: justified with last line aligned left. No indent on first paragraphs. Times Font.

TEXT BODY

Body of the text is justified with last line aligned left, single spaced, Times Font (10pt), no indent on first paragraphs, indent on subsequent paragraphs.

ACKNOWLEDGMENTS

Section heading set flush left, **boldface**, *italics,* no numbering. Per AIP, include acknowledgments of financial support in this section.

Acknowledgments

FOOTNOTES

Footnotes notated by superscript, italic *i, ii, iii*   Vaporization[i]   Imaging[ii]

REFERENCES (See references Appendix B)

In-Text Citations

In-text citations are by reference numbers set as superscripts placed logically, in numerical order of first appearance by the content referenced.

In-text reference numbers always follow comma and period, and precede semicolon and colon:

diameter.[4]   diameter[4];

Running-text references to authors:

Use last name only.

Name both authors for two authors: “Smith and Jones found…”

Use “et al.” for three or more authors: “Smith et al. found…”

References Section

References Section heading set as an H1 heading: **boldface**, centered, no number: **References**

Order of references: a numbered list that corresponds to the numbered, in-text citations.

Author Name Presentation

Invert all authors’ names; give surnames and initials (if provided) with space between and periods.

Include all authors if given (no “et al.”)

Commas separate authors; no “and” before last author; comma ends the list:

Bushman, B. A., Bonacci, A. M., Miller, G.,

Publication

See Appendix A for examples

Journal articles

Titles are not given.

Abbreviated journal name follows author list, Title Case, space but no comma after.

Volume number, boldface, follows journal name with lightface comma after.

Issue number, if available, in parens closed up to **vol number**, lightface, then lightface comma.

First page number follows comma after **volume**(issue) with a space after.

Year of publication in parens following the space after page number.

Closing period for the entry.

Bushman, B. A., Bonacci, A. M., Miller, G., App. Opt. **55**(2), 97 (2015).

Journal articles in press

Title of article follows author list, Title Case, *italics*, comma after.

Abbreviated journal name, comma, (in press)

Closing period for the entry.

Miller, S. A., D'Andrea, J. A., Cook, M. C., Chalfin, S., Ziriax, J., Parker, J. E., III, Beason, C. W., McQuade, J. S., *Summary of Results from the Active Denial Biological Effects Research Program*, J. Dir. Energy. (in press).

Books

Book Title follows author list, set Title Case *italics*, followed by a comma.
City of publication follows, if given, with colon after.
Publisher name follows city (or title if no city given) with a space after.
Year of publication follows publisher name, in parens.
Closing period for the entry.

Merritt, P., *Beam Control for Laser Systems*, Albuquerque: Directed Energy Professional Society (2012).
Merritt, P., *Beam Control for Laser Systems*, Directed Energy Professional Society (2012).

Proceedings

Name of Presentation follows author list, set in Title case italics, with comma after, followed by Proc. abbreviated Conference name.
Location of conference (if available), space after, year of publication follows conference name, in parens.
Closing period for the entry.

Kelley, D. F., *A Reactively Controlled Array over Ground Plane for Hemispherical Coverage*, Proc. IEEE Int. Symp. Antenn. Propag. (2008).

Legal, Public and Unpublished Materials

Title of Document italics follows author list, with comma after
Source type identifier, with comma after
Place of Publication, with comma after
If applicable, list type with space after
(year of publication)
Closing period for the entry.

Beason, C. W., *Main Beam Power Determination from Interference Patterns*, Air Force Research Laboratory, Fort Sam Houston, TX, Unpublished manuscript (2015).

Technical Report / Review

Title of Document italics follows author list, with comma after
Publisher, with comma after
Place of Publication, (comma, document number if given) (comma, page numbers if given) with

space after
(year of publication)
Closing period for the entry.

J. M. Finnegan, R. Borges, R. M. Wightman, *Comparison of Cytosolic Ca2+ and Exocytosis Responses from Single Rat and Bovine Chromaffin Cells*, Dept. Chem., Univ. of North Carolina at Chapel Hill, Chapel Hill, USA, Rep. ONR-TR-11 (1995).

Theses and Dissertations

Title of Document italics follows author list, with comma after
Thesis type, comma after,
University of study, comma after,
Location with space after
(year of publication)
Closing period for the entry.

E. C. M. Boyle, III, *Millimeter Wave Effects,* M.A. thesis, Dept. English, Purdue Univ., West Lafayette, IN, USA (2017).

USAGE AND GENERAL STYLE MATTERS

Point of View and Verb Tense
"We," "our" may be used by one or multiple authors; "I" by a single author.
"The author(s)" may be used but be clear or avoid this if outside authors have also been referred to.
Avoid passive voice unless recasting the content becomes cumbersome.

TYPOGRAPHY

Spacing
All content set with single space between sentences.

Italics
Mathematical variables (symbols for physical quantities)
Emphasis (but sparingly)
Words as words (e.g., we use the word *theory*); for letters as letters (e.g., the letter *K*)
Scientific names (*genus species*)
Watercraft, aircraft, spacecraft
Latin phrases if uncommon, as indicated by the discipline (e.g., *ad infinitum*)
Books, journals, and other publications (e.g., online media) per *CMOS*

Roman
Symbols for units
Subscripts and superscripts unless they are themselves a variable

Greek letters
Letters as shapes (e.g., Y-shaped)
Parentheses and other fences regardless of enclosed content

Boldface
Parentheses in headings; otherwise not used in main content

Fences
Work outward with parentheses according to the scheme **{ [( )] }**
Square brackets for a parenthetical remark that already contains parentheses: Recall [see Eq. (A4)]
Keep parentheses intact in multiple citations: In Eqs. (13), (14), and (16)   [not (13, 14, 16)]
Use parentheses in citing equations and figure parts: In Eq. (13)   In Fig. 4(a)

PUNCTUATION

Dashes and Hyphens
En dash for ranges
En dash for coequal word compounds and names formed from 2 people's names (e.g., dose–effective response, cost–utility analysis; Guillain–Barré syndrome)
Minus sign for negative numbers
Hyphen with units used adjectivally: 1-kg wrench

NUMBERS

Spell out numbers <10 unless used with a unit of measure or as part of a comparison with numbers >10 (e.g., 5 to 15 repetitions)
Spell out numbers that begin a sentence or recast to avoid this.

EQUATIONS

The Times or Times New Roman font (10pt) should be used for the equations when feasible.

All equations should be numbered, to the right of the equation, written in parantheses.

$$b = \iint f_r \,\beta\mathrm{n} \pm d\phi \qquad (1)$$

Callouts in text, all set roman.
In running text, if beginning a sentence: Equation 9 shows . . .
In running text, if embedded in a sentence: In Eq. 9 . . .
Single digit numbering style (1, 2, 3, . . .)

FIGURES

Callouts in text, all set roman.
In running text, if beginning a sentence: Figure 9 shows . . .
In running text, if embedded in a sentence: In Fig. 9 . . .
In parentheticals: Temperature is a major factor (Fig. 9).
Single digit numbering style (1, 2, 3, . . .)

Figure Number and Caption
Fig. 10. [boldface, with boldface period] Barometric pressure effects. [Sentence case, ending punctuation] **Fig. 10.** Barometric pressure effects.

Figure Labels
All labels, including graph axis labels are set Sentence case, with no ending punctuation
All labels are in Times Font, Roman
Units are (in parentheses)
Legends set as indicated by authors

Creation
Access to original figures and graphics is always preferred. Please retain any files you have created your figure in, and request originals for ones you do not have. Save figures/graphics as a PDF when possible - preserving any fonts or designs as vector graphics is always best. When using pixel-based graphics, please save it in the highest possible resolution (minimum of 300 dpi at the size they will appear, typically 5" x 4").

TABLES

Callouts in text, all set roman.
In running text: . . . as reported in Table 2.
In parentheticals: Temperature is a major factor (see Table 2).
Single digit numbering style (1, 2, 3, . . .)

Table NumberTitle, and Style
Table 2. [boldface, with boldface period, Times Font] Barometric Pressure Effects. [Title Case, no ending punctuation]

Column headers: boldface, Sentence case, with units in parentheses: **Observed Wavelength (nm)**
First column is left justified, others centered, if it looks correct.

Appendix A: REFERENCE EXAMPLES AND JOURNAL ABBREVIATIONS

Journals

1. Landy, N. I., Sajuyigbe, S., Mock, J. J., et al., Phys. Rev. Lett. **100**, 207402 (2008).

2. Shalaev, V. M., Cai, W., Chettiar, u. K., et al., Opt. Lett. **30**(5), 3356 (2005).
3. Schurig, D., Mock, J. J., Justice, B. J., et al., Science **314**(5801), 977 (2006).

Books

6. Engheta, N., Ziolkowski, R. W., *Metamaterials: Physics and Engineering Explorations,* New York: Wiley-IEEE Press (2006).
7. Jin, J., *The Finite Element Method in Electromagnetics*, 2nd ed., New York: Wiley (2001).

Proceedings and Presentations

8. Kelley, D. F., *A Reactively Controlled Array over Ground Plane for Hemispherical Coverage*, Proc. IEEE Int. Symp. Antenn. Propag. (2008).
9. Legg, R., Singer, F., *Status of the Wisconsin SRF Gun*, Proc. 2012 Int'l Part. Accel. Conf., New Orleans, LA (2012).
10. Sannibale, G., et al., *Status of the APEX project at LBNL*, Proc. 2014 Int'l Part. Accel. Conf., Dresden, Germany (2014).
11. Hurt, J. M., Kosub, W. D., *Facial Detection of 94 GHz Millimeter Waves by the Nonhuman Primate, J.A.* Paper presented at the Bioelectromagnetics Soc. Annual Meeting, Long Beach, CA, June 20–24 (1999).

Technical Report / Review / Publication / Government Doc

Finnegan, J. M., Borges, R. M., Wightman, P., *Comparison of Cytosolic Ca2+ and Exocytosis Responses from Single Rat and Bovine Chromaffin Cells*, Dept. Chem. Rep. ONR-TR-11, Univ. of North Carolina, Chapel Hill, NC (1995).

D'Andrea, J. A., Cox, D., Henry, P. J., Ziriax, J. M., Hatcher, D. J., Hurt, W. D., *Rhesus Monkey Aversion Thresholds to 94-GHz Facial Exposures*, DoD Technical Report No. DEBL-2006-08, Naval Health Research Center Detachment, Brooks City-Base, TX (2006).

Murphy, M. R., Merritt, J. H., Mason, P. A., D'Andrea, J. A., Blick, D. W., Scholl, D. W., *Bioeffects Research in Support of the Active Denial System (ADS): A Novel Directed Energy Non-Lethal Weapon*, In Non-Lethal Capabilities Facing Emerging Threats, Fraunhofer Institut Chemische Technologie, Ettlingen, Germany, 23.1 (2003).

Department of Defense (DoD), *Use of Animals in DoD Programs*, DoD Instruction Number 3216.01 (2010). Retrieved February 21, 2017, from http://www.dtic.mil/whs/directives/corres/pdf/321601p.pdf

U.S. Air Force Armstrong Laboratory, (U) *Active Denial Technology Research: Final Report*, Brooks AFB, TX, Unpublished classified report (1997).

Beason, C. W., *Main Beam Power Determination from Interference Patterns*, Air Force Research Laboratory, Brooks City-Base, TX, Unpublished manuscript (2009).

Theses and Dissertations

Boyle, E. C., *Millimeter Wave Effects,* M.A. thesis, Dept. English, Purdue Univ., West Lafayette, IN (2017).

Appendix B: EXAMPLES OF VARIATIONS IN HEADINGS AND LISTS

8. Quantitative Risk Assessment Guidelines for LPB

When quantifying acceptable probabilities of failure for military applications, a safe assumption would be to establish that LPB shall be as safe as commercial aircraft regarding *PoF*. Table 3 utilizes likelihood values quantified by the International Civil Aviation Organization (ICAO) in ICAO Doc 9859—Safety Management Manual.[16] Consequences of failure, detailed previously, are highly dependent on wavelength, irradiance, and exposure time of the laser used for power beaming. From Table 3, the consequences are quantified to fully define a quantitative risk assessment for LPB. We recommend that Table 3 be utilized with the color-coded risk assessment matrix in Fig. 9 when evaluating LPB safety systems.

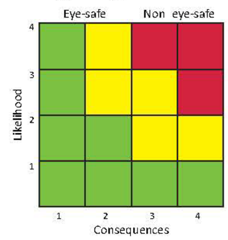

Fig. 9. Risk assessment matrix template.

9. LPB Mission Scenarios

The following represent what CERDEC's wireless power team considers candidate mission scenarios that would benefit from laser power beaming with basic size, weight, and power (SWAP) requirements considered. Due to power beaming in free space and in potentially chaotic environments, these applications all would require robust safety system implementation.

Scenario 1: Unmanned ground vehicle power beaming

Unmanned ground vehicles (UGVs) provide a versatile platform to act as an extension into hostile territory while minimizing direct risk to the soldier from enemy fire. UGVs can act as both forward scouts to a squad as decoys to broadcast radio frequencies away from a squad to better remain undetected from adversaries. This buffer from direct threats can be maintained via optical power links from LPB. Laser power transmitters can be towed on the back of an all-terrain military vehicle tasked with securing the perimeter for an incoming force. The trailer would leverage existing fielded equipment such as the CERBERUS[17] operational surveillance system with power beaming optics for transmission above the eye level of soldiers. For this scenario, size and power requirements of the QinetiQ TALON[18] were used as a model of typical UGV specifications, assuming a photovoltaic conversion efficiency of 30%.[19]

If the laser transmitter is elevated such as shown in Fig. 10, no direct line-of-sight hazard is presented to soldiers near the laser transmitter. As the laser propagates toward the UGV, risk increases for humans in its vicinity. If reliable safety controls are implemented, eye-safe wavelengths are used, and soldiers do not approach forward-operating UGVs during charging, overall risk is predicted to be low.

Scenario 2: Small unmanned aerial system power beaming

Threat identification utilizing low-altitude intelligence, surveillance, and reconnaissance (ISR) unmanned aerial systems (UAS) became standard during recent wars in Iraq and their real lasting legacy beyond demonstrating the possibility of controlled flight was the basic principle of raising one side of the wing while lowering the other, the shape of the propeller and the training of the first generation of pilots. It was Glenn Curtiss, one of the original members of the Aerial Experiment Association (AEA), founded by Alexander Graham Bell, who won the transition war and made the first truly useful aircraft on a large scale. The Wright brothers and their company only built about 120 planes.[5] By comparison, the Curtiss Aviation company sold over 6000 JN-4 (Jenny) airplanes, only one of several production models, by 1919.

The success of the Curtiss airplanes stemmed from several factors. First, Curtiss was chosen as a member of the AEA in part because he was already the head of a motorcycle and aviation engine manufacturing company.[4] Curtiss came later to the building of flying machines, 1907, than did the Wright brothers, but his technical approach rapidly outpaced theirs and it is Glenn Curtiss who is the true father of American civil, naval, and military aviation. Curtiss's approach to engineering can perhaps be best illustrated by his invention of the pontoon plane, then called a hydroaeroplane. Curtiss started by putting canoes on the landing skids of the AEA June Bug and kept the speed down until the first issue arose—the plane started to nose down due to drag. He then went back to the shop and modified the shape of the canoes, then back to the lake solving a variety of lift, drag, and stability issues one at a time using what we would now call an experimentation and prototyping approach until he had a plane that could take off and land from the water, later implemented on a Curtiss model D. Curtiss aircraft were the product of a collaborative association with people of differing technical backgrounds. He ran his company the same way—getting a diverse pool of the best talent and actively seeking collaborative ventures.

By contrast, the Wright brothers were spending most of their energy during this time period in fighting patent wars, attempting to stop others from manufacturing airplanes and demanding exorbitant licensing fees (about 20% of the sales price). The Wrights were notoriously averse to anyone else's technology—at one point Glen Curtiss offered them one of his aviation engines for free. The offered engine was 50 hp and nearly double the power-to-weight ratio of the Wright 1908 4-40 engine. They turned him down. Time that could have been spent improving airplanes, improving manufacturing, or making planes more useful was lost to "not invented here."

Third lesson: Multi-disciplinary manufacturing, experimentation, interdisciplinary engineering, and prototyping with an interface-driven approach beats a technology-centric approach, especially if the technologists are stove-piped or are waiting until TRL4 or TRL5 to include interface considerations.

1.2 Optimization problem of product development

There are three general acquisition lessons that can be drawn from the early history of flight:

- A technology-centric approach (making a component technology and then figuring out its interfaces) will reach TRL3 first and then fail, requiring extensive re-designs that may or may not happen (Langley).
- An interface-driven approach (letting interfaces guide technology development) that ignores manufacturing or the broader view of interfaces, will reach TRL4 first and then stagnate (Wright brothers).

transmit capability. This existing RF bottleneck on an MQ-9 is mitigated by lasercomm data rates. Both air-to-ground and air-to-air data rates of 10 Gbps over distances greater than 167 km (100 mi) have been demonstrated.[1,2]

2. Why Lasercomm?

GA-ASI is developing ALCOS for use on its family of UAVs. The advantages of lasercomm follow:

- Anti-jam
- Low probability of interception/low probability of detection (LPI/LPD)
- High data rate
- Unlimited spectrum

2.1 Anti-jam

It is extremely difficult to gain entry into a coherent spacecraft lasercomm receiver. As shown in Table 1, with a receive field of view (FOV) of 30 μrad, the resulting footprint on Earth from a GEOSAT, is approximately 1 km. With a satellite using a laser receiver, an adversary would have to be within 1 km of the aircraft to have a potential line of sight (LOS) into the satellite receiver. In our application, the satellite uses a homodyne receiver that demodulates the incoming beam using synchronous detection. To gain entry into the satellite homodyne receiver, the frequency of the adversary laser must (virtually) *exactly* match the frequency of the local oscillator of the satellite receiver. Without this frequency match, the incoming beam cannot access the coherent receiver. Even if an adversary laser beam entered the lasercomm-receiver optical FOV, it would not gain entry into the homodyne receiver unless its frequency matched that of the local oscillator.

If the RF satellite receive (Rx) antenna FOV were ½°, the area on Earth with an LOS into the satellite Rx antenna is a roughly circular area of 312-km diameter, over two orders of magnitude larger than that of a lasercomm receiver.

Table 1. GEO Comm Links: Resulting Earth Footprints

GEO comm link	Space Rx FOV	Zone on Earth with LOS into space receiver	
		Diameter	Area
Laser	30 μrad	1.07 km^2	0.9 km^2
RF	½°	312 km^2	76,415 km^2
RF	1°	624 km^2	305,660 km^2

2.2 LPI/LPD

With an extremely narrow UAV transmit (Tx) beam divergence, it is extremely unlikely that an adversary would either detect the UAV transmission or be able to intercept it. A laser beam with a divergence of 30 μrad, would only grow to a diameter of 1.1 m at the top of the stratosphere (48 km). With minimal scattering of the Tx beam, as it emanates from an airborne platform at an altitude of 12.20 km (40,000 ft), it would be difficult for