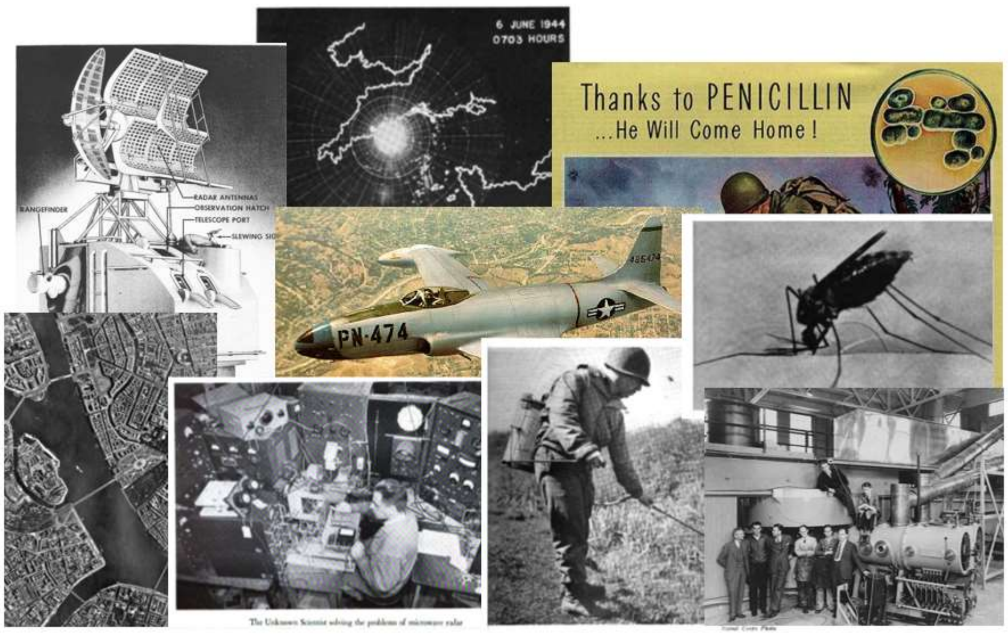
Data and Metrics for Evaluating DOD SBIR/STTR Impact: *Finding "invisible" innovation*

DANIEL P. GROSS | DECEMBER 7, 2023

DUKE FUQUA SCHOOL OF BUSINESS

Defense innovation:
Critical technology areas then vs. now



Source: (1) Gross, Daniel P. and Bhaven N. Sampat. 2023. "America, Jump-started: World War II R&D and the Takeoff of the U.S. Innovation System," *American Economic Review*, 113(12), 3323-3356. (2) https://www.cto.mil/ndsts/

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Agenda: The Three S's

1. Software
2. Secrecy
3. Selective engagement

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Pop quiz: A moonshot

• How many lines of code were in the Apollo Guidance Computer (1969)?	~145,000
• How many in the original Space Shuttle (1981)?	~400,000
• How many in a Lockheed F-35 JSF (2006)?	>8 million (>24 million in support)
• How many in Army Future Combat Systems (cancelled 2009)?	>63 million

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Software is eating the world

- "More and more major businesses and industries are being run on software and delivered as online services—from movies to agriculture to national defense." –Marc Andreessen, 2011

- DoD innovation used to be (and still is) very hardware-intensive

- But many ongoing changes:
  - Hardware systems are developed with increasingly-more software
  - Intelligence harnesses digital information
  - Weapons (and arenas) of war now include cyberspace

Sources: https://www.wsj.com/articles/SB10001424053111903480904576512250915629460

Software is eating the world (and DoD?)

- Anduril blog: "American technological supremacy will require a **pivot from the large, exquisite, hardware-defined systems** that won us the conflicts of last century to larger numbers of lower-cost, **attritable, smaller, software-defined systems**."
    - "Such a sweeping redesign of the military will require a **fundamental shift from hardware-first to software-first acquisition**"

- "The majority of DoD's stated technology priorities — including autonomy; command, control, and communications (C3); cybersecurity; missile defense; and artificial intelligence/machine learning — are **driven by advances in software**."
    - "Consider swarming munitions, autonomous UAVs, or cruise missile defense systems: The **hardware components** of each of these systems **are not difficult to build or novel**. What is difficult to build, **what is novel about them, is the software** that makes these very capabilities possible. It is **software, not hardware, that enables** swarming, autonomy, or missile detection. The shiny hardware encasing these systems is a side show — it is the quality of the software that determines the system's efficacy."

Sources: https://blog.anduril.com/in-the-21st-century-the-department-of-defense-must-think-software-first-36802bd4be65

PLAY THE CROSSWORD

Account

The New York Times

A.I. Brings the Robot Wingman to Aerial Combat

An Air Force program shows how the Pentagon is starting to embrace the potential of a rapidly emerging technology, with far-reaching implications for war-fighting tactics, military culture and the defense industry.

Excerpts:

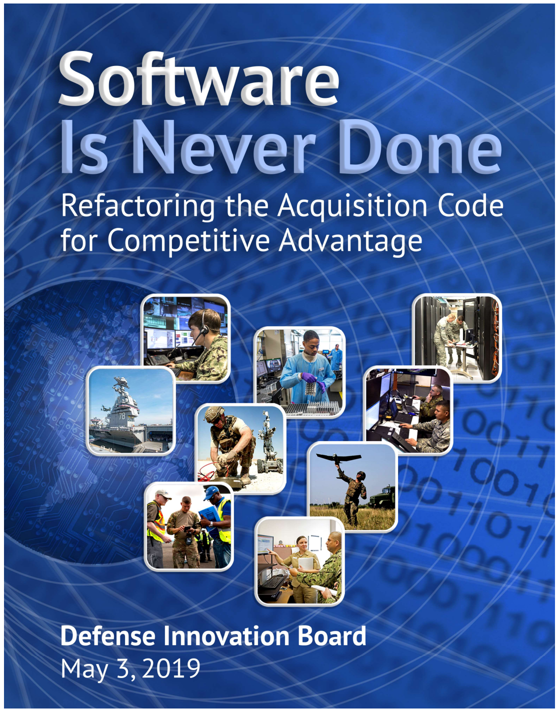
- Humans will continue to play a central role in the **new vision for the Air Force**, … they will **increasingly be teamed with software engineers** … who will be constantly refining **algorithms** governing the operation of the **robot wingmen** that will fly alongside them.

- The Air Force is planning to **split up the aircraft and the software** as separate purchases.

- A separate set of **software-first companies**—tech start-ups such as Shield AI and Anduril that are funded by hundreds of millions of dollars in venture capital—are vying for the right to **sell the Pentagon the artificial intelligence algorithms** that will handle mission decisions.

Growing subject of attention in DoD policy analysis, planning, acquisition

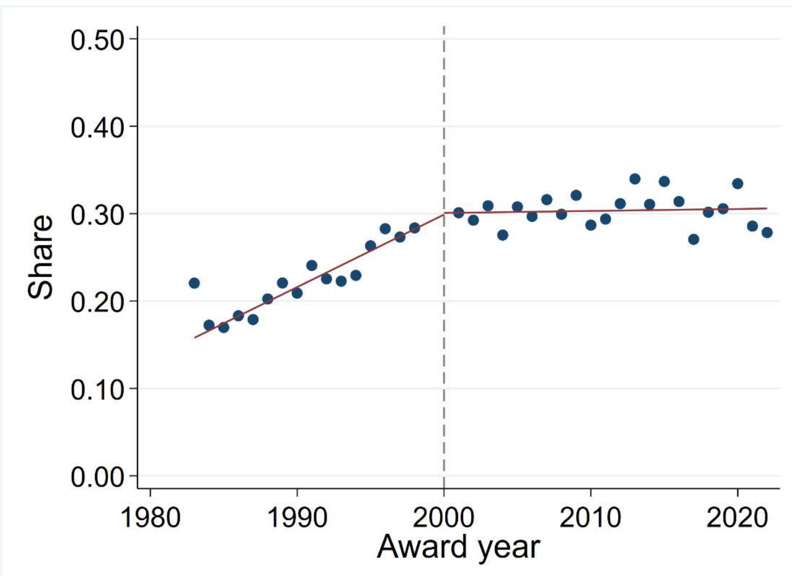
- Defense Innovation Board (DIB) Software Acquisition and Practices Study (SWAP)
  - Recommendation: "*Create a new appropriation category for software capability delivery that allows (relevant types of) software to be funded as a single budget item, with no separation between RDT&E, production, and sustainment.*"



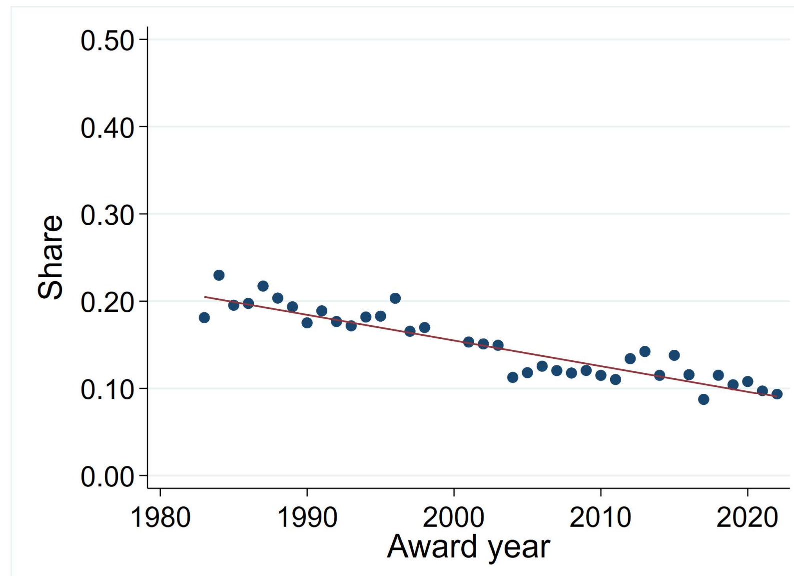
Is software eating SBIR? (It already did)

Share of DoD SBIR awards w/ select text in abstract, 1980-2022

Software | Algorithm | Simulation | Programming



Computers | Computation ("Comput")



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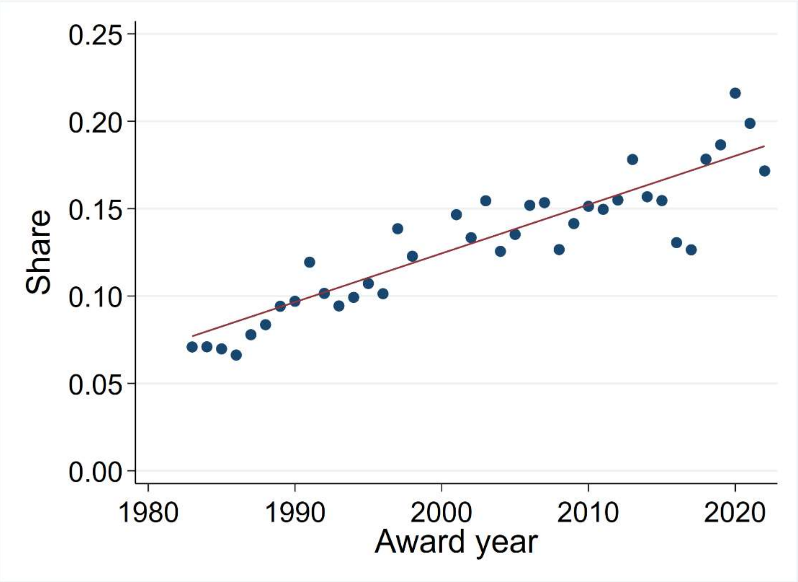
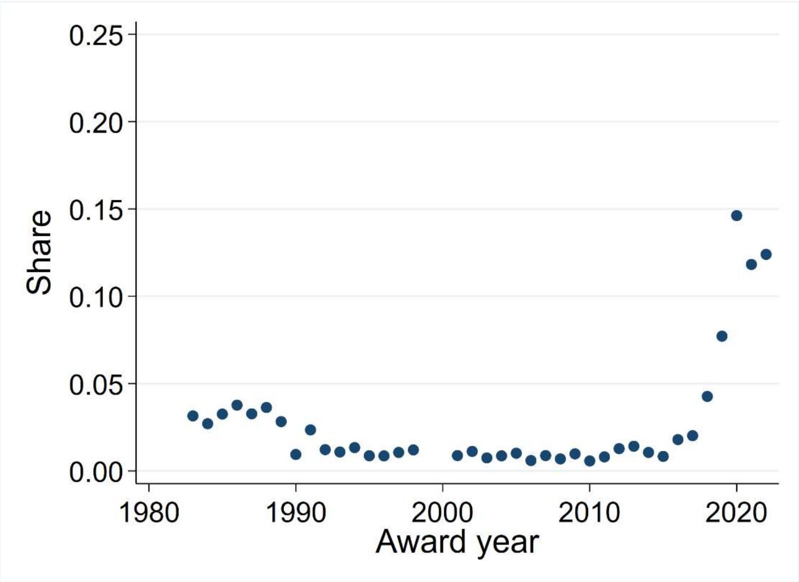
Long-term and recent growth drivers

Share of DoD SBIR awards w/ select text in abstract, 1980-2022

Autonomy | Automation (“Autonom”/“Aotumat”)



AI/ML (“Artificial intel”/“Machine learn”)



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Measuring defense software innovation

- Hard problem: conventional metrics (patents/publications) not as helpful
  - Patents: software generally not patentable
  - Publications may be useful for measuring some algorithm development

- New RDT&E budget activity code (FY2021): 6.8 (Software and Digital Tech Pilots)
  - But: only identifies dedicated software R&D projects
  - Thus far limited in scope: ~0.5% of DoD RDT&E budget

- Other approaches: textual analysis? What else?
  - How to measure software intensity in physical systems?

Agenda: The Three S's

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2. Secrecy
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[CHAPTER 501]

July 1, 1940
[H. R. 10058]
[Public, No. 700]

AN ACT

To amend the Act relating to preventing the publication of inventions in the national interest, and for other purposes.

Public Law 256

CHAPTER 4

February 1, 1952
[H.R.4687]

AN ACT

To provide for the withholding of certain patents that might be detrimental to the national security, and for other purposes.

35 USC 188

NB: This unofficial compilation of the U.S. Code is current as of Jan. 4, 2012 (see http://www.law.cornell.edu/uscode/uscprint.html).

TITLE 35 - PATENTS

PART II - PATENTABILITY OF INVENTIONS AND GRANT OF PATENTS

CHAPTER 17 - SECRECY OF CERTAIN INVENTIONS AND FILING APPLICATIONS IN FOREIGN COUNTRY

What a secrecy order does

- Halts examination: application goes under seal
- Prohibits publication or disclosure of invention
- Prohibits filing in a foreign country
- Permits that the invention be disclosed to relevant agencies (e.g., DoD)
- Inventor can claim royalties for government use
- Subject to annual renewal (possibly indefinitely)

- Penalties for violating:
  - Lose patent, fined up to $10K, jail for up to 2 years

Source: Invention Secrecy Act of 1951 and subsequent amendments. See 35 USC 17.

Historical origins in wartime (WWI/WWII)

In WW2 (1940-1945): around 5% of USPTO-filed inventions ordered into secrecy—over 11K total

Serial No.	Inventor	Title	Assignee
D-104,614	William P. Yant	Facepiece for Breathing Apparatus	Mine Safety Appliances Co.
D-105,236	John B. Littlefield et al.	Breathing Apparatus	Mine Safety Appliances Co.
333,158	Hugo Benioff	Electroacoustic Transducer	Submarine Signal Co.
338,949	James B. Fisk	Producing and Transmitting Electromagnetic Waves	Bell Telephone Labts., Inc.
344,363	Hugo Benioff	Piezoelectric Oscillator	Submarine Signal Co.
407,461	Milton E. Mohr	Electrical Wave Trans-forming System	Bell Telephone Labts. Inc.
428,698	Wilmer L. Barrow et al	Radio Target Detector	Sperry Gyroscope Co.
429,508	William W. Hansen et al	High Frequency Power Measuring Device	Sperry Gyroscope Co.
442,477	Alfred Henry Chilton	Electrically Propelled Torpedoes	

Source: Gross (2023), "The Hidden Costs of Securing Innovation: The Manifold Impacts of Compulsory Invention Secrecy," *Management Science*, 69(4), 2318-2338.

May 17, 1955

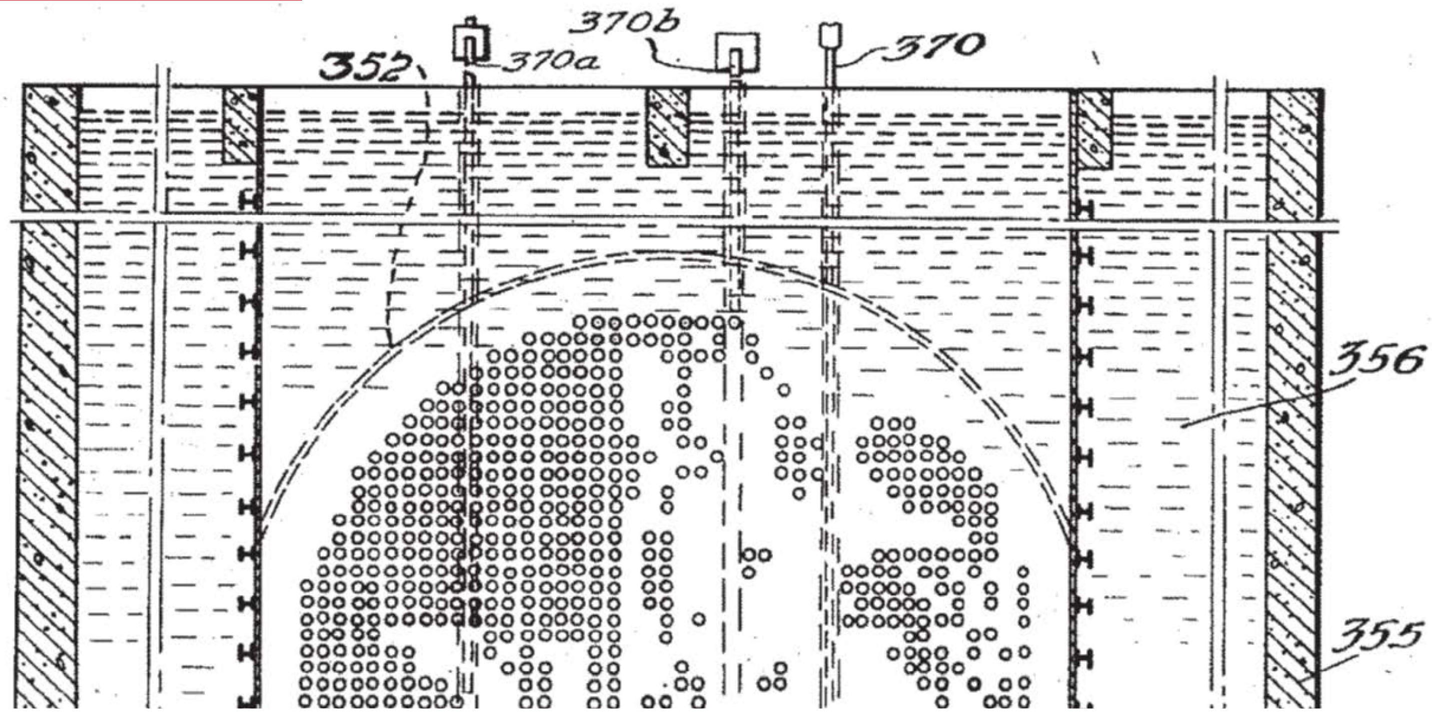
E. FERMI ET AL

2,708,656

NEUTRONIC REACTOR

Filed Dec. 19, 1944

27 Sheets-Sheet 25



Compulsory secrecy in WWII:
Quasi-experimental evidence

Panel (A): Filing dates of non-Manhattan Project secret patents

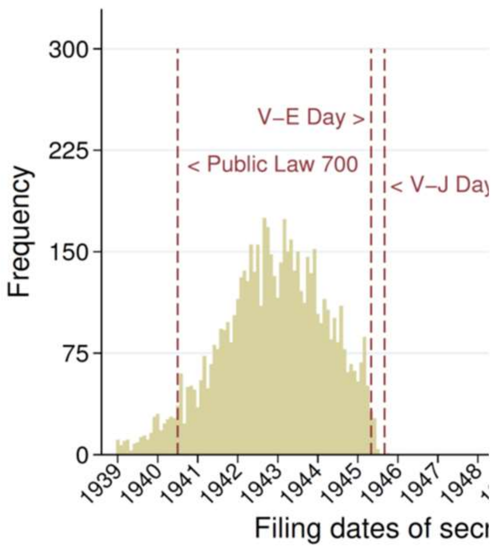
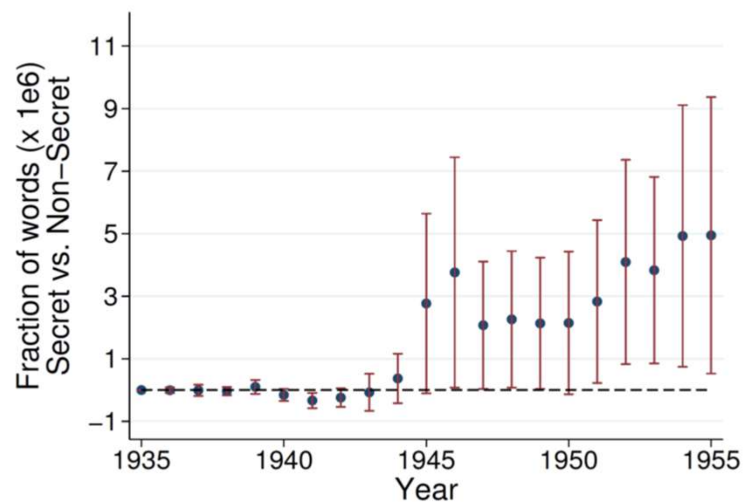


Figure 4: Annual use of new word stems from secret vs. non-secret patent titles, measuring use in patents' full text



Source: Gross, Daniel P. 2023. "The Hidden Costs of Securing Innovation: The Manifold Impacts of Compulsory Invention Secrecy," *Management Science*, 69(4), 2318-2338.

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Impacts of compulsory secrecy in WWII:
Good for NatSec, bad for private sector

- Broad range of innovation ordered into secrecy during the war
  - Not just nuclear fission: radar, electronic communication, synthetic rubber, cryptography

- Evidence of impacts of compulsory secrecy:
  1. These inventions less likely to be built upon (follow-on invention)
  2. Could not be commercialized while secrecy order was in effect

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Secrecy orders: Stats in 2023

Today: ~0.02% of USPTO-filed inventions (100-150/year) ordered into secrecy

- Probably defense-specific, but don't know

ACTIVITY	FY23	
New Secrecy Orders	125	Flow
SO Rescinds processed	27	
Total SO's in effect, end of period	6155	Stock
Sponsoring Agencies for new SO's		
Foreign Origin	0	0.0%
ARMY	17	13.6%
NAVY	55	44.0%
AF	43	34.4%
DOE	7	5.6%
NSA	0	0.0%
DTSA	2	1.6%
NASA, DARPA	1	0.8%
New DOD SO's imposed by Type		
DOD Type 1 (export control)	84	67.2%
DOD Type 2 (classified/classifiable)	8	6.4%
DOD Type 2 (foreign PSA)	0	0.0%
DOD Type 3	26	20.8%
New Non-DOD SO's imposed (DOE,NASA)	7	5.6%
John Doe SO's	25	

Source: Aftergood (2023), "FAS Project on Government Secrecy". Available at https://sgp.fas.org/othergov/invention/index.html. Accessed December 2, 2023.

Example: Laser-tracking system

… Filed Apr 1989

… Issued Jun 2015

Source: Aftergood (2023), "FAS Project on Government Secrecy". Available at https://sgp.fas.org/othergov/invention/index.html. Accessed December 2, 2023.

(12) **United States Patent**
Fink

(10) **Patent No.:** **US 9,057,604 B1**
(45) **Date of Patent:** **Jun. 16, 2015**

(54) **POINT-AHEAD LASER POINTER-TRACKER SYSTEMS WITH WAVEFRONT CORRECTION IN BOTH TRANSMIT AND RECEIVE DIRECTIONS**

(75) Inventor: **David Fink**, Los Angeles, CA (US)

(73) Assignee: **Raytheon Company**, Waltham, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **07/338,009**

(22) Filed: **Apr. 14, 1989**

(51) **Int. Cl.**
G01B 11/26 (2006.01)
G01C 1/00 (2006.01)

(52) **U.S. Cl.**
CPC . ***G01B 11/26*** (2013.01); *G01C 1/00* (2013.01)

(58) **Field of Classification Search**
CPC G01B 11/26; G01C 1/00
USPC .... 356/139, 139.01–139.1, 152, 356/152.1–152.3; 89/1.11; 250/201 R–203 R, 201–203; 455/611
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,437,825 A * 4/1969 Studebaker 356/3.12

* cited by examiner

Primary Examiner — Luke Ratcliffe
(74) *Attorney, Agent, or Firm* — Donald F. Mofford

(57) **ABSTRACT**

Point-ahead laser pointer-tracker systems with stabilization and wavefront correction in both transmit and receive directions provide arrangements for sensing the wavefront correction required in two different directions, one in the received target image direction for good image quality in the tracker and the other in the point-ahead direction for good beam quality on the target. In the several embodiments, a marker beam is aligned with the target image. Wavefront aberration correction signals are produced by an output wave sensor that senses the wavefront of the marker beam in the received target image direction and the wavefront of the source laser beam in the point-ahead transmit direction. The alignment is maintained by use of the output wave sensor signals together with signals from the tracker of the target and current aimpoint positions. These signals, compared in selected pairs, control mirrors in various legs of the optical system to put the current aimpoint on the desired aimpoint and to align the marker beam along the received target image direction.

11 Claims, 15 Drawing Sheets

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Selective participation in SBIR

- Growing software requirements of defense R&D programs (among other things) point towards increased need to engage commercial sector and widen the application funnel

- What stops firms from engaging with DoD SBIR?
  - Arcane and burdensome acquisition regulations
  - Slow contract awards—can take over a year to begin
  - Low probability of procurement or recurring revenue
  - Inability to conduct or incorporate classified work

- Who's not engaging with SBIR and why?
  - A different kind of measurement challenge: what goes missing?

Thank you

For follow-up questions or discussion, please email

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