Sat, Aug 16, 19:30-20:30, rm 447-448, 2025 Seattle WorldCon Panel TEC16 **Current Lasers to Future Phasers!**:
"The last time Worldcon was in Seattle, lasers were two years old, big, expensive, and found only in labs. Now they can be tiny, cheap, and found everywhere. They are used everywhere from the battlefield to the operating room to anywhere a cat needs to be amused. What else are they used for? What will the future bring? Join our panelists as they shed light on this topic to form a coherent picture of what is to come."

My original description: **"**Join us for a discussion of current uses of lasers, near-term developments, and your favorite Science Fiction counterparts. Scientific research, medical applications, and (of course) battlefield blasting included! Everything directed-energy in fandom is fair game too, from Buck Roger's Ray Guns of the 1930s to Star Blazer's Wave-Motion Gun that does ANYTHING the writers need it to do!*"*

Bob Hranek (mod), **Alon Newton, J. L. Doty, Jack Glassman, Leanna Cosplay**

Bob Hranek [My career began with 6 years of USAF Computer Programming plus 34 more years as an Aerospace Systems Engineer. Since I was a Defense Contractor for the Intelligence Community, I'm usually depicted as representing *the Dark Side* on panels. Hence my 'Protogen' name plate, which fans of ***The Expanse*** will understand. That being said, I do NOT speak for ANY of my employers! This panel is an extension of my life-long fascination with lasers, science fiction, & my professional curiosity of the evolution of current energy weapons. I OVERprepare for all my panels, so if you'd like my extensive notes for Lasers to Phasers, then just email me at BobHranek@gmail.com]

Terminology:
Maser, "microwave amplification by stimulated emission of radiation", created in 1953, very useful for precise timing.
Laser, "light amplification by stimulated emission of radiation", 1st built in 1960, by Ted Maiman in CA.
Laser light is *coherent* allowing a laser beam to stay narrow over great distances (collimation).
X-ray Laser, 1st demonstrated in 2009 at Stanford, was important for Strategic Defense Initiative (SDI)/*Star Wars*.
Saser, "Sound amplification by stimulated emission of radiation", 1st developed in 2009, likely useful in optoelectronics.
Graser, "Gamma-ray Laser", not yet achieved(?), should allow next leap in research, computer technology, & weaponry.

Real World LASER/MASER/other Uses:
1) **Active Sensors** (LIDAR), very precise picture/map making using millions of point-by-point distance measurements.
2) **Passive Sensors**, laser-scanned vibrations off of other objects can be used to record conversations even without LOS.
    a. Threat Warning (EM Detection).
3) **Laser Communications** are much harder to intercept & have a much higher data rate (>10x) than Radio Frequencies (RF).
4) **Ring Laser Gyroscopes** (RLGs) bias uncertainty < 0.01°/hour, mean time to failure > 60,000 hours, cost < mechanical.
5) **Laser checkout scanners** are so cheap, accurate, & convenient that they've taken over most stores in U.S.
6) **Laser Surgery** & industrial **Cutting** better than mechanical: easier holding & reduced contamination of the workpiece.
7) **Computer-chip lithography**, essential for making the integrated circuits that our civilization relies on.
8) **High-precision timing**, such as femtosecond (10^{-15} second) accuracy.
9) **Research**: 2023/09/19, record-breaking X-ray laser is ready to unlock quantum secrets.
10) **Attack**: {**DE** = Directed Energy, **EM** = Electro-Magnetic, **RF** = Radio Frequency}
    a. Electronic Warfare (EW):Attack (EA)/Support(ES)&Protection(EP)/Electro-Magnetic Battle Management (EMBM)
    b. Cyber/Infiltration
        i. RF DE Weapon → Induced voltage and current (V&I) → digital data into circuits & devices.
        ii. ES/EA Systems → Signals → Signal Processing or Protocols.
        iii. RF Cyber-Delivery Platforms → Code & Data → Data Processing.
    c. Directed Energy (DE) of any EM wavelength
        i. Problems:
            1. **Power** hungry, Lasers requiring ~300 kW to defeat drones, rockets, artillery, and mortars.
            2. **Targeting** must be extremely focused, precise, and accurate for an effective weapon.
            3. **Slew Rate** must enable keeping DE on the target until desired effect is achieved.
            4. **Dwell Time** must be long enough to keep DE on the target until desired effect is achieved.

ii. Desired Effects:
    1. **Blinding** of sensors is sometimes sufficient, and even desired (if no permanent damage is done, then there's much less likely to be an international incident).
    2. **Burning** out electronics or cutting a hole in a hypersonic target will effectively destroy it.
    3. **Blasting** to complete destruction requires so much power & dwell time that it's unlikely.

Real World Examples (emphasis on reporting Weapon-related uses here):

11) Fighting Artificial Intelligence Battles Operational Concepts for Future AI-Enabled Wars, 117 pgs, Peter Layton, 2021.
    a. [Central combat service support core] "nodes may need comprehensive defence packages to protect them, including layered counter-rocket artillery and mortar systems, high energy lasers, high-powered microwaves, jamming, ground-based air defences, electronic deception & perhaps even limited ballistic missile defence."
12) China: Multi-Domain Precision Warfare in 2042.
    a. 2023/01/05, China developing own version of JADC2 to counter US (Joint All-Domain Command & Control).
    b. 2023/10/25, China's "Multi-Domain Precision Warfare" Operational Concept "Mirrors" US Strategy, Directed Energy weaponry part of multifaceted plan to gain tactical & strategic battlefield advantages by 2042.
13) Microwave Technology
    a. 2019: The Active Denial System (ADS) is designed for area denial, perimeter security, & crowd control. ADS can only penetrate 1/64" of skin, but most test subjects reached their pain threshold in 3 seconds, and none could endure more than 5 seconds. ADS induced 2nd-degree burns in < 0.1% of its test subjects.
    b. 2019: Anti-vehicle system looks like an old-time phonograph, can fit in the bed of a truck, with a range of 50 meters. The jammer works by targeting the car's engine control unit causing it to reboot over and over, stalling the engine, without damaging the vehicle, its driver, or anyone else.
    c. 2021/03/30, LM's MORFIUS "is a reusable, multi-engagement, loitering, tube-launched interceptor equipped with an onboard seeker and a compact, high-power microwave effector to execute non-kinetic defeat of drones – including complex swarms."
    d. Yarkovsky effect: any DE-induced heat can be shed to provide a relative thrust on a space object.
        i. Can be used to aid in clearing space junk out of LEO, asteroid deflection, and/or military purposes.
14) **Laser Pointer**s, <5 mW visibly (400-700 nm), not just for playing with Cats, >150,000,000 made every year.
15) **Laser Scanners** & computer Mice, estimated to be a $4.5 billion global market in 2023. 800,000 **LASIK** surgeries/year.
16) **Laser Light Shows** & **Holograms**, world record 3.8x3.8km(14,500,000m²) 2022 show in Riyadh & 9x15m hologram in Las Vegas.
17) Low-Power Laser, Non-Lethal, emit < 10,000 Joules (the energy required to kill a human)
    a. Protocol on Blinding Laser Weapons does not prohibit attacks against binoculars, periscopes, telescopes, & other optical equipment because it's unknown if attacks on such devices could cause permanent blindness.
    b. 2019/07/19, Plasma Laser Balls for non-lethal weapons: 2 lasers used together to create ear-splitting sounds near (or ***talk*** to) target. 1st laser pulses to create plasma + 2nd beams straight into resulting ball of ionizing gas.
18) 2024/12/23, AWST, p15, **Laser Designators** (precision targeting) so small they can be flown on Elbit's *Thor* mini-UAVs.
19) 2025/05/05, AWST, p40, **Laser Alignment** used in **precision construction**, such as Turkey's Kaan Fighter development.
20) 2023/05/29, NASA's Laser Link Boasts Record-Breaking 200-Gb/s Speed: "satellite could transmit more than 2 terabytes of data—roughly 1,000 high-definition movies—in a single 5-min pass over a ground station."
    a. 2024/05/05, NASA Extends Laser Communication in Space to 226 Million Km, to Psyche spacecraft. Transmitting a complete Mars map to Earth would take ~9 weeks by RF, but only 9 days by laser, and use smaller equipment & less energy, both at a premium on spacecraft.
    b. Mynaric Laser communications completed demonstration for U.S. Defense Space Architecture in June 2022.
21) 2025/04/07, AWST, p38, **Laser Comm Links** for Space Development Agency (SDA) 500 LEO satellites, $7 billion by 2033.
22) 2025/05/05, AWST, p47, **laser cross-links** on Amazon's Kuiper satellite constellation, for rapid secure communications.
23) 2025/07/28, USSF-36 To Test **Laser Links** & Quantum inertial navigation Sensor on new X-37B Mission, >8/21 launch.
24) 2025/07/14 AW&ST p12 & DARPA quantum apertures, one 1cm³ laser sensor can detect 10 MHz – 40 GHz signals.
    a. Combined with AI processing, this means the end of stealth for any platform emitting >1 milliwatt of energy.

25) 2025/06/02, AWST, p74, Optical Air Data Systems (OADS) **Laser Doppler Velocimetry** (LDV) precision aircraft landing, in any weather, at any speed, eye-safe, & miniaturized (1.4 kg) for use in **Optical Moon Proximity Sensors** (OMPS).
    a. Also extends the reach of Drone Warfare, since this works in GPS-denied environments.
26) 2024/11/11, AWST, p46, **Astro Forge**'s 2030 plan to use **Laser Ablation** to refine asteroid platinum for return to Earth.
    a. Goal is to bring back ~1,100 kg platinum-group metals to Earth for about ~$70,000,000 return per mission.
27) **Selective Laser Sintering** 3D Printing to turn small particles of polymer powder into complex, tough, functional parts.
28) **Industrial Cutting**, such as KAAST Precision Cutting 12 kW Lasers, & **Welding** at Germany's Fraunhofer Institute.
29) 2020 LM Tactical Airborne Laser Pods Are Coming, building on >40 years laser weapon development & relevant Tech.
    a. High Energy Laser and Integrated Optical-dazzler with Surveillance (**HELIOS**) system integrating onto U.S. Navy destroyers to protect sailors and ships from attack by drones and small boats.
        i. AN/SEQ-3 Laser Weapon System, bulky trickle charge capacitors, long charge time, difficulty tracking small targets, & problems producing one synchronized & coherent beam from the 6 smaller emitters.
        ii. 2022/03/31, HELIOS Delivered for Installation on USS Preble, 60-120 kW vs Anti-Ship Cruise Missiles.
            1. It has replaced the Preble's forward Mk15 Close-In Weapon System.
            2. Surprisingly short range, solid-state HELIOS laser only considered effective to several miles.
        iii. 2024/10/15, Destroyer USS Preble arrives in Japan armed with high-energy laser weapon, 60 kW.
    b. 2024/12/23, AWST, p41, F-35 laser countermeasure upgrade to jam IR SAMs or destroy incoming missiles.
    c. 300 kW-class Indirect Fire Precision Capabilities High Energy Laser (**IFPC-HEL**) demonstrator, a ground vehicle system to defeat drones, rockets, artillery and mortars for U.S. Army.
        i. 2023/09/21, 4 Laser prototype systems delivered to 4-60th Air Defense Artillery Regiment, Ft Sill, OK.
            1. Directed Energy Maneuver-Short Range Air Defense (**DE M-SHORAD**) on Stryker light armor.
        ii. 2023/07/28, LM to Scale Laser to 500 kW, 2nd part of High Energy Laser Scaling Initiative (HELSI).
        iii. 2024/05/06, "U.S. Military Is Using Laser Weapons in Battle," Forbes. 20 kW P-HEL anti-drone laser.
        iv. 2025/05/05, AWST, p37, **US Army** testing **50-kW laser** on Stryker & **20-kW lasers** integrated onto 2 Infantry Squad Vehicles (ISV) & 2 Joint Light Tactical Vehicles (JLTV) seeking mass production in 2026.
            1. 20-kW lasers use a 15-cm aperture. 50-kW laser uses a 20-cm aperture.
    d. Self-Protect High Energy Laser Demonstrator (**SHiELD**) system for USAF: developing critical components of an airborne laser pod including the high-energy laser & other subsystems planned for mid-2020s demo.
        i. 2019/05/03, USAF Research Lab (AFRL) completes successful shoot down of air-launched missiles.
            1. 4/23 test of Laser Advancements for Next-generation Compact Environments (LANCE).
        ii. 2021/10/06, LM Delivers High Energy Laser to USAF for Flight Testing on AC-130J. (AHEL)
        iii. 2024/03/19, USAF dream-of-mounting-laser-weapon on AC-130j Ghostrider Gunship is Dead.
        iv. 2024/05/17 USAF Abandons planned Laser Weapon for Fighter Jets, such as F-15, F-22 & F-35.
30) 2022/04/25, Israeli 100 kW **Iron Beam Drone Killing Laser**, "costs $3.50 per shot", but doesn't replace Iron Dome system yet, mostly due to weather-related performance limitations.
    a. 2024/11/11, AWST, p8, Israel awarded Rafael & Elbit Systems $540 million to expand Iron Beam production.
    b. 2025/05/22, Science News, Golden Dome plan has a major obstacle: Physics, U.S. current $60 billion limited kinetic-kill ICBM-intercept capability is unlikely to improve in next 15 years & tested as only 60% effective.
        i. "Ensuring protection from just 1 North Korean ICBM would require > 1,000 interceptors in orbit, the APS report finds. Protection from 10 might demand > 30,000 interceptors, depending on missile type & other assumptions." Since it can't defend against a massive attack, we're back to MAD.
        ii. "May 5 Congressional Budget Office report suggests that, even with lower launch costs, the space-based effort alone would cost between $161 billion and $542 billion over a period of 20 years."
    c. 2025/06/02, AWST, p16, ULA CEO Tory "Bruno proposed space-based high-energy lasers powered by chemically fueled electric generators or a small nuclear reactor" as part of the Golden Dome SDI recreation.
    d. 2025/07/14, AWST, p16-17, $25 billion to start Golden Dome, with +$175 billion to *try* to field it by 2029.
        i. Low probability of success, but using AI-controlled lasers instead of kinetic-kill gives it a higher chance.

31) 2025/06/02, AWST, p20, DARPA tested laser to relay >800 watts 8.6 km during 30-sec as phase 1 of Persistent Optical Wireless Energy Relay (**POWER**) program, envisioned as an **energy web of Class 2 or 3 UAVs flying at 18 km** altitude.
    a. Phase 2 started 5/29, 6-month goal to transmit 3 kW to end receiver, with aerial relay using 600 W for itself.
    b. Phase 3 goal: deliver 5 kW at ground 200 km thru 3 airborne relays, to remotely power autonomous warfare.
    c. 2025/02/24, AWST, p53, similar tech proposed to **power lunar excavators** in permanently shadowed regions.
32) 1989/07, Los Alamos Neutral Particle Beam (NPB) Accelerator Experiment was successfully tested at 200 Km altitude.
33) Lockheed Martin is working on making a **Phaser**! Yeah, it's not called that, yet, but it should be!
    a. It's called a "**Matter Laser**", designed to deliver 10^6 times greater energy than a Laser.
        i. UV Laser photons max out at 25 eV, coherent matter wave particle has 25 Mev.
    b. Patent issued Nov **2016** to Lockheed Martin, US 9502202 "**Systems and methods for generating coherent matterwave beams**" using the Aharonov-Bohm effect to induce coherence in particles without the exchange of energy. https://patents.google.com/patent/US9502202B2/en
    c. Can be used to produce a gamma-ray-laser for uses where EM radiation is better.
    d. Can also be used for on-board Geo-Navigation with greater accuracy than GPS.
34) 2024/07/17, @CleoAbram reports This Is A Real Life **Tractor Beam**, but only for particles ~100 microns, so far.
    a. Details in this High Efficiency Triple-Helix Solenoid Beam Generated by Dielectric Metasurface article.
35) Laser Interferometer Gravitational-Wave Observatory (LIGO)'s extreme precision (<10^{-18}m) is only possible with lasers.
    a. Opened a new realm of Astronomy: detecting highest energy events since the Big Bang, black hole mergers.
    b. Use Gravitational-Wave Observatory Status for each location and Look Deeper for a real Tech deep dive.
36) 2015/09/01, How the Universe Works – Forces of Mass Construction, Dr Jena Meinecke uses highest-power lasers at Lawrence Livermeore National Ignition Facility to create scaled astrophysical objects such as mini-supernovas and analyze their shockwaves to unravel the mysteries behind the origin of magnetic fields in our universe.

Lasers/Phasers/Blasters/Particle-Beams/Other in Science Fiction:

37) **Babylon 5** Energy Weapons are interchangeably described as lasers, particle beams, or other terms.
    a. "PPG (Phased Plasma Gun) fires a bolt of energized, super-heated helium sheathed in EM field & propelled by opposed magnetic field. On impact, the plasma bolt dissipates & discharges its thermal & kinetic energy."
38) **Battlestar Galactica** Original Series Weapons, conjectured to be more like particle beams, but most fans don't care.
39) **Doctor Who** Horror of Fang Rock episode has the Doctor using some small "diamonds to focus the [early 20th century] lighthouse beam, converting it into a high-energy laser, and destroying the Rutan mothership."
    a. **K-9's Nose Laser** gets its own sub-entry here, just because it's the coolest dog in all of Time & Space! Watch New Effects - K9 Laser to see how they changed its depiction from a wide-beam to a focused laser.
40) **Dune Lasgun**, most widely used gun in Imperium, adjustable width beam, hitting a shield creates a nuclear explosion.
41) **Earthlight** (1955) in which Arthur C Clarke envisaged a particle beam weapon (EM-propelled bayonet of liquid metal).
42) **Ender's Game** (1985+) **Glaser** is a Gravity laser designed to disrupt asteroids for mining. The twin-beam **Molecular Disruption Device** created a chain-reaction breaking molecular bonds, which could vaporize a closely-spaced fleet or devastate the entire surface of a planet.
43) **Flash Gordon** Ray Gun details are scarce. It basically did whatever the writers said it did, just like Star Trek much later.
44) **Halo Universe** Covenant's Plasma weapons can be a single bolt, beam, or continuous stream, up to planet Glassing.
45) **Hammer's Slammers Powerguns** scale from 1cm pistols to starship killing sizes, deliver devastating power (hence the name), but apparently dissipate All their energy hitting the first bit of solid matter they encounter, even a small bush!
46) **Honor Harrington** Honorverse Lasers "were the most common ship-mounted energy weapon. Anti-ship lasers had lenses that ranged from several decimeters to over a meter in diameter and operate in the X-ray range[1]; they had effective ranges of about 1,000,000 kilometers (500,000 km against targets with sidewalls). A majority of ships also mounted clusters of smaller point defense lasers for the anti-missile duty, that were powerful enough to destroy shuttlecraft. Grasers were a larger, more powerful version of lasers, and operate in the gamma ray range."
47) **Lensman series** (1948-1954) E.E. Smith's Ray Projectors span needle-rays up to **Sunbeams**, focusing all a star's output.
48) **Space Battleship Yamato's Wave-Motion Gun** has got to take the cake in the Superweapon hall of fame.

49) **Star Trek** "Patterns of Force" episode has Spock using laser made from 2 *rubindium* communication crystals to cut jail door bolt in seconds powered by a bit of light from 1 small light bulb!
50) **Star Trek Phasers** are INFINITELY adjustable:
    a. Starship phasers even capable of using the *Stun* setting from orbit, as in the A Piece of the Action episode.
    b. Hand phasers can magically disintegrate (leaving virtually no trace) a target, without damaging anything else!
51) **Star Wars** hand **Blasters** also have Stun and Kill settings.
52) **Star Wars Lightsabers** are often called 'Laser Swords' & do far less damage than they should! Watch Kyle Hill's video!
    a. A blade like that, that can slice through metal, would explosively vaporize any flesh it came in contact with!
53) **Star Wars** Death Star Superlaser is infinitely scalable, even allowing complete destruction of a planet with one shot!
54) **Star Wars** Starkiller Base is ridiculous in Force Awakens, but much better explained by the writers of Wookieepedia.
55) **Stargate Weapons:** the stun/kill/disintegrate **Zat gun**, **Plasma Staffs**, & galaxy destroying **Dakara superweapon**!
56) **The Expanse**, lasers play no role in personal or spaceship combat, but are integral to their fusion powerplants.
57) **The Last Starfighter Death Blossom** of "laser blasts & photon bolts" wipes out EVERYTHING within a short range.
58) **The Terminator** series, pulse lasers are widely used in the future, replacing slug-throwing guns.
59) **Traveller** 1977 RPG has Lasers of all sizes, from pistols to spacecraft cannons, & **Meson Guns** for larger spacecraft.
60) **War of the Worlds Heat Rays** are typically depicted as laser-like.
61) **Warhammer 40,000** Imperial Guard use **Lasgun**s, as extensively described in their Lexicanum page.
62) PANEL DISCUSSION:
    a. What are your favorite lasers in real life and in science fiction? [*RjH: RL=The ones being developed for Laser Inertial Fusion Energy*; *SF=Star Trek Phasers for their silly Infinitely selective & completely clean destruction.*]
    b. What do you consider the most ridiculous use of lasers in real life and in science fiction? [*RjH: in RL, the use of Laser pointers to amuse Cats. In SF, Starkiller Base is too ridiculous by those with the budget to do BETTER!*]
    c. What are the most surprising directed-energy developments you'd like to share? [RjH: If we haven't discussed it already, then I'd like to make sure the audience is aware of Lockheed Martin's *Phaser* work.]
        i. **Jack Glassman**: Any favorite anecdotes you'd care to share from your work at AFRL, Lawrence Livermore, or the Nevada Terawatt Facility?
63) **Alon Newton**'s additional links:
    a. LIGO Gravitational-Wave Antenna's IEEE milestone commemorative plaque at Hanford, WA, Site.
    b. Easy demos at Music-Driven-Laser-Pointer-Lightshow & Simple-and-Cheap-Laser-Digital-Audio-Transmission.
    c. If there's extra time, **Alon** can talk about the-history-of-fiber-optics-timeline.