Wootton Center for Astrophysical Plasma Properties, Department of Astronomy

2515 Speedway, C1400 • Austin, TX 78712-1205 • 512-471-3000 • FAX 512-471-6016
www.as.utexas.edu

Center Scientific Advisory Committee meeting for the Wootton Center for Astrophysical Plasma Properties

Meeting date: 16 January 2020

Location: POB Building, The University of Texas at Austin, Austin, TX

Members of Center Scientific Advisory Committee meeting (CSAC) for the Wootton Center for Astrophysical Plasma Properties (WCAPP) present:

Nancy Brickhouse, Harvard-Smithsonian Center for Astrophysics
Chris Fontes, Los Alamos National Laboratory
David Kilcrease, Los Alamos National Laboratory
Don Lamb, Department of Astronomy and Astrophysics, University of Chicago
Keith Matzen, Sandia National Laboratories, Albuquerque
Marilyn Schneider, Lawrence Livermore National Laboratory
Hugh Van Horn, Department of Physics and Astronomy, University of Rochester (retired)
Alan Wootton (retired)

Don Lamb and Hugh Van Horn attended via video conference.
Meeting held at The University of Texas at Austin campus.

Contents

1. Summary

The Wootton Center for Astrophysical Plasma Properties (WCAPP) is engaged in an exciting research program, and has now been up and running for 2 years. It is built on the PI's and Co PIs' successful ~5-year Fundamental Science Program at the Z facility at Sandia National Laboratories (SNL), which included the precursor ZAPP (Z Astrophysical Plasma Properties) program. The research focus remains unique: The atomic and radiation physics of warm- and high-energy-density plasmas. The "at parameter" experiments, producing high-fidelity data, are resulting in publications with high impact for both astrophysical and Department of Energy (DOE) / National Nuclear Security Administration (NNSA) interests. Efficient use of the Z facility continues by fielding multiple experiments (typically 4) on every shot. The Center has also been awarded time on the National Ignition Facility (NIF); this will extend the region of parameter space available for study and afford further high visibility. The Center continues to provide an education leading to a source of young scientists in the important area of atomic and radiation physics of warm dense matter.

The committee meeting demonstrated that the team, a combination of experimental, theoretical, and computational scientists, is well aware of the challenges involved in meeting the Center's objectives. An important and well-understood challenge continues to be finding sufficient high-quality graduate students and postdocs for doing numerical simulations and the experiments. This reflects the general shortage of highly qualified young scientists in the field of atomic and radiation physics of warm dense matter. Helping to remedy this shortage is one objective of the Center.

Findings and Recommendations are given in individual sections, and also in the Final Summary.

2. Introduction

The Wootton Center for Astrophysical Plasma Properties (WCAPP) received its first funding in February 2018. It is focused on the atomic and radiation physics of matter over a wide range of temperatures and densities. Academics currently funded by the grant are from the University of Texas at Austin (UT) and the University of Nevada, Reno (UNR). The experiments are currently undertaken at the Sandia National Laboratories (SNL) Z Facility. In addition to the heavily involved SNL staff, there is significant staff participation from Lawrence Livermore National Laboratory (LLNL) and Los Alamos National Laboratory (LANL), as well as from the University of Arizona and NASA. Motivated by astrophysics, the Center simultaneously addresses problems of interest for stockpile stewardship, Inertial Confinement Fusion (ICF), and High-Energy-Density (HED) physics. This document is a summary of the second meeting of the Center's Scientific Advisory Committee (CSAC).

The panel met from 8:30 am to 5:00 pm on Thursday January 16, 2020; the meeting agenda is listed in the Appendix. After introductions, WCAPP Director Don Winget summarized the Center's response to the CSAC 2019 Findings and Recommendations, and areas where advice is now requested. Jim Bailey of SNL then discussed the evolving relation of WCAPP to SNL. There followed presentations on current and near-term (~3 year, i.e. up to year 5 after Center start) experiments and modeling research by the following people: Jim Bailey of SNL on Solar Opacities, Roberto Mancini of UNR on Photoionized Plasmas, Bart Dunlap and Mike

Montgomery of UT on White Dwarfs, Don Winget and Mike Montgomery on Plans for NIF, and Ben Thomas (UT) on Machine Learning Applied to Data Base Analysis. Details are found in the Appendix.

After a general discussion with WCAPP researchers (including students) around focused questions, the committee met alone for discussions on the following questions and topics:

Near term (the next 2 years, i.e. year 3 to 5 after Center start)

- Is the proposed research world class?
- Is it likely to be approved for time on Z?
- Are the right tools in place or being developed?
- Is the research planning, especially for human effort (including postdocs, students, additional institutions) adequate for success?

Future years (Year 4 after Center initiation and beyond)

- Exploratory Studies
- Is it the right time to be evaluating what could be done not only "at parameter on Z" but also on lasers, including scaled experiments?
- Strategies for Renewal

3. Discussion, Findings and Recommendations

A lively and constructive discussion, first with the Center members, and then amongst just the committee members, ensued. We summarize these discussions below, including our Findings and Recommendations.

3.1 Near term (the next ~2 years)

3.1.1 Research quality

The Wootton Center for Astrophysical Plasma Properties (WCAPP), headquartered at the University of Texas at Austin (UT), is carrying out experiments whose aim is to improve our understanding of (1) white-dwarf photospheres and radiative envelopes, (2) opacities in the Sun and related stars, (3) the radiation from black-hole accretion disks, and (4) the atomic physics and X-ray heating of photoionized plasmas. All of the experiments are at the forefront of research in their respective areas, and all are related to the properties of high-energy-density plasmas. The Center's unique approach is to combine observational astronomy, laboratory experiments (currently performed at the Z Facility at SNL), theory, and modeling. An important objective is to train graduate students and postdocs (in experiment, theory and modeling) in the atomic and radiation physics of warm- and high-energy-density plasmas, and to expose them to the capabilities of the NNSA national security laboratories.

The white-dwarf work is truly world class. At UT, Don Winget, the Center's Director, and Mike Montgomery, the Center's Deputy Director, are recognized world leaders in the study of white dwarf stars. During the past century, these small, dense objects have gone from being astronomical curiosities to being well-understood types of stars that are now being used as tools to investigate various types of stellar binaries and even to help determine the age of the Milky

Way Galaxy. However, discrepancies between theoretical calculations and experimental measurements of the properties of photospheric absorption-line profiles make the masses derived from white-dwarf models uncertain. This translates, for example, into uncertainties in the age of the Galactic Disk. The dense-plasma experiments conducted at the Z Facility by the WCAPP investigators are providing direct measurements of the properties of spectral lines under conditions appropriate to white-dwarf photospheres, with the aim of reducing or eliminating these uncertainties.

Similarly, differences in the properties of the subsurface convection zone in the Sun, as determined from evolutionary solar models and helioseismology, are potentially due to uncertainties in the iron opacity near the base of the solar convection zone. This is a critical problem in stellar astrophysics, because the Sun is our touchstone for understanding other stars. Jim Bailey (recipient of the 2016 John Dawson Award for Excellence in Plasma Physics Research) and his colleagues at SNL are recognized leaders in Z-pinch experiments at SNL. Their work employs the megajoule-class facility to produce dense-plasma samples that are large enough to enable direct measurements of iron opacities and radiative transfer under conditions like those at the base of the solar convection zone. They have been carrying out benchmark experiments that are accurate and reproducible, and which provide tests of theory that address this problem directly. Their work has the potential to resolve this important dilemma.

Noting that all current models of the radiation from black-hole accretion disks disagree with the observational data, Guillaume Loisel and his colleagues have been utilizing Z-pinch data to construct a laboratory analog to benchmark models of X-ray emission from accretion-powered plasmas. They recently discovered that simultaneous line observations contradict the long-standing assumption that resonant Auger destruction is 100% effective, an assumption that has often been used to interpret the spectra of black-hole accretion disks. Their work has already helped to stimulate improvements in the codes used to model the emission from hot plasmas. It is likely to become even more important with the planned launch of the X-Ray Imaging and Spectroscopy Mission (XRISM) in five years or so.

Roberto Mancini and his group at the University of Nevada at Reno (UNR) are carrying out work designed to understand the fundamental atomic physics involved in the ionization of dense plasmas. They use the Z Facility at SNL as well as the smaller Zebra facility at UNR to produce ionized plasmas and provide the X-ray backlighting needed to measure the fractional populations and charge-state distributions of highly ionized Ne. Current astrophysical codes overestimate the electron temperature in astronomical sources, and these investigations can test the reasons for this experimentally. Mancini's group has been very successful in producing Ph.D. graduates who have joined SNL and other U.S. National Security Laboratories.

Finding 1:

WCAPP is conducting important experiments on the Z Facility and has identified and is pursuing opportunities for additional experiments to study the properties of spectral lines in white dwarf photospheres and envelopes, opacities in the Sun and related stars, and black-hole accretion disks.

Recommendation 1:

a. *WCAPP is strongly encouraged to focus on its Z-pinch experiments to measure the properties of spectra under 1) conditions relevant to white dwarf atmospheres and 2) the opacities of iron under conditions relevant to the interior of the Sun in the next two years.*
b. *WCAPP has been awarded shot days on the National Ignition Facility (NIF) under the Discovery Science Program to conduct experiments that have the potential to improve our understanding of the physical properties of matter at the base of the subsurface convection zone in the Sun and white dwarfs. The CSAC endorses these experiments (which will likely take place in the final year of the current 5-year period of performance of the Center and beyond) and encourages WCAPP to do everything necessary to ensure that these experiments are successful.*
c. *WCAPP is encouraged to explore opportunities to conduct dense-plasma experiments at the Omega laser facility at the University of Rochester in the last year of the current 5-year period of performance of the Center and beyond.*
d. *WCAPP is encouraged to investigate the potential utilization of scaled experiments or micro-equivalence in the last year of the current 5-year period of performance of the Center and beyond.*
e. *WCAPP is encouraged to prepare for opportunities to utilize their white-dwarf results in support of the flood of observational data anticipated from the Vera Rubin Observatory (formerly the Large Synoptic Survey Telescope) by the end of 2021.*

***Finding 2*:**

Continuing to provide a pool of graduate students and postdocs trained in the atomic and radiation physics of warm- and high-energy-density plasmas, from which the National Laboratories can seek to recruit staff, is an important goal of WCAPP.

***Recommendation 2*:**

WCAPP is strongly encouraged to continue to train graduate students and postdocs in undertaking experiments, theory and numerical simulations of atomic physics experiments, and in so doing, to expose them to the facilities and the work in this area at the NNSA national security laboratories.

3.1.2 Performing the experiments at Z

Finding 3:

The research of the WCAPP team on Z, performed in collaboration with staff from SNL, LLNL, and LANL, is likely to continue to produce outstanding scientific results. While the UT proposals to the Z Fundamental Science Program (ZFSP) continue to be highly rated and approved for experimental time on Z, the UNR proposals need to be strengthened to be competitive.

Recommendation 3:

a. *Given the established record of this team on the Z Facility, the priority order for experiments on laboratory facilities over the next three years should be the following: Z, NIF, Omega.*
b. *With the ZFSP call now moving to an annual basis with shots each year allocated for the following 2-3 years, it is important for the WCAPP team to submit annual proposals for*

research that will bear fruit for the "at parameter" astrophysics experiments while developing new insights and experimental capabilities for the stockpile stewardship program.

c. *Stay disciplined with respect to physics focus and shot selection.*
d. *In addition to modeling the atomic and radiation physics for these Z experiments, the WCAPP team might consider multi-dimensional radiation-hydrodynamics modeling of the target configurations to optimize experimental designs and interpretation of the experiments.*
e. *Always remember that the Z Facility is not a national user facility (and all that this situation entails).*

3.1.3 Relevant tools

Interpreting the results of high-energy-density plasma experiments requires the use of a variety of sophisticated computer codes. Some are commercial, some are available at the US national laboratories, and others have been developed and are maintained at universities.

With PrismSPECT, users can investigate how plasma spectral properties change with plasma conditions. For a grid of user-specified plasma conditions, PrismSPECT computes spectral properties (emission and absorption) and ionization properties for LTE and non-LTE plasmas.

SPECT3D is a multi-dimensional imaging and spectral analysis package. SPECT3D is typically used to post-process results from hydrodynamics simulations to compute images and spectra that can be directly compared with experimental data.

HELIOS is a 1-D radiation-hydrodynamics code designed to study the hydrodynamic evolution of radiating plasmas. It can be used to study the evolution of planar, cylindrical, or spherical plasmas heated by laser beams or by external radiation sources. Sample uses of HELIOS include simulating the dynamics of laser-produced plasmas, discharge-produced plasmas (z-pinches), radiatively-heated plasmas, as well as shock propagation in materials. HELIOS-CR is an enhanced version of HELIOS that includes the option to simulate the dynamics of non-Local-Thermodynamic-Equilibrium (NLTE) plasmas using an inline Collisional-Radiative (CR) model.

Other non-commercial modeling tools are also available. XSTAR is a computer program for calculating the physical conditions and emission spectra of photoionized gases. It is being used to model the photoionized plasma experiment at Sandia. Its oscillator strength database has been updated based on these Sandia Z Facility experiments.

Of interest are publicly available radiation hydrodynamics MHD simulation codes capable of simulating high energy density experiments. These include the FLASH code. FLASH employs novel numerical methods and algorithms to solve complex non-linear systems, and is expected to provide insight into the conditions of the plasmas being interrogated. The Z Facility experiments – and the forthcoming NIF experiments and the possible Omega experiments – are complex, difficult, expensive and rare. High-fidelity validated numerical simulations are essential for designing and executing successful experiments at these facilities. Depending on the committee member, such simulations either "can be useful", or "are essential for" interpreting the results. They also provide a path for recruiting undergraduate students, graduate students and postdocs.

There was no disagreement that, given sufficient manpower, undergraduate or graduate students could be trained to utilize the FLASH code, although it was noted that a previous attempt to utilize the code was not successful. The committee discussion involved prioritizing experiments, including those specifically designed to investigate possible plasma platform issues, versus 3-dimensional modeling of the platform. Another question discussed was whether a student could be found who could undertake the modeling work while also satisfying the astrophysics and atomic physics objectives of the WCAPP.

Graduate student Patricia Cho is on track to update the spectral line shapes relevant for white dwarfs in the TLUSTY code using line shapes generated with Thomas Gomez's line shape code ZENOMORPH. TLUSTY is a program for calculating plane-parallel, horizontally homogeneous model stellar atmospheres in radiative and hydrostatic equilibrium. Departures from local thermodynamic equilibrium (LTE) are allowed for a set of occupation numbers of selected atomic and ionic energy levels. The program also allows for convection.

Other modeling codes that have been employed by the center's collaborators include CLOUDY (Cloudy is a spectral synthesis code designed to simulate conditions in interstellar matter under a broad range of conditions) and ATOMIC (ATOMIC is a Los Alamos NLTE atomic physics spectral modeling code that can also account for the time evolution of NLTE electron populations).

Concluding this section, there was not unanimity as to whether, as in last year's report, the project has adequate tools for analysis of its experiments. The difference of opinions concerned the priority of deploying the FLASH code to predict the experimental plasma platform's properties.

Finding 4:

A number of plasma and spectral modeling tools are currently in use and available for analysis of the various plasma spectroscopy experiments being conducted. There was not unanimity on the priority of utilizing the FLASH code. Depending on the committee member, high-fidelity validated numerical simulations (3-dimensional) either "are essential" or "can be useful" for interpreting the results.

Recommendation 4:

The main deficiency in this area is the shortage of personnel in the center to make full use of these tools. Depending on the committee member:

Either:

a. *If manpower shortages are alleviated, and if a suitable student or students become available, another attempt to utilize the FLASH code should be made.*

Or:

b. *WCAPP is strongly encouraged to conduct high-fidelity, validated numerical simulations of past and future experiments using, e.g., the FLASH code.*
c. *WCAPP is strongly encouraged to recruit an undergraduate or two and a graduate student who would learn how to conduct such simulations.*

3.1.4 Research planning, especially for human effort

It is important to strike a proper balance between graduate students and postdocs, between experiments and data (i.e. obtaining new data versus analyzing existing data), and between theory and simulation. As discussed in last year's report, having the appropriate personnel to do this is crucial for the Center to achieve its goals. The Center was then, and is still, understaffed, and recruiting graduate students and filling the remaining postdoc positions is still of highest priority.

UT has one graduate student, Patty Cho, in Albuquerque supporting the experimental campaigns at SNL. Roberto Mancini at UNR is mentoring two graduate students in plasma modeling. However, no new graduate students were hired during the past year, which is a point of concern. Don Winget and Mike Montgomery have both invested a significant amount of time in outreach efforts, such as attending OMEGA Laser Facility Users Group (OLUG) meetings, giving presentations at national and international conferences that are frequented by graduate students with the desired skill sets, and serving on the graduate student recruiting committee for the UT Astronomy Department. These efforts did not yield any new graduate students, but they did allow for the identification of certain trends and possible improvements for attracting graduate students to the Center. In particular, the Center leadership explained that highly qualified graduate student candidates have typically carried out 3 or 4 research projects during their undergraduate studies and already have a good idea of what type of PhD research they would like to do before arriving at UT. This suggests that undergraduates must be made more aware of the Center.

The Center made a postdoc offer to a qualified candidate, who had to withdraw due to family health issues. Another graduate student, Lisa Lobling from Germany, has been identified as a potential postdoc, and is being considered now.

Finding 5:

Recruiting and hiring graduate students and postdocs is of highest priority, and this requires making undergraduates and graduate students more aware of the research opportunities offered by WCAPP.

Recommendation 5:

Options for enhancing the recruitment of graduate students and postdocs include (with some questions):

a. *A great website*
b. *Information near the entrance to the RLM building on the UT Austin campus.*
c. *Participation (if is possible) in any UT Austin Physics Department programs that highlight faculty research to the graduate students.*
d. *Exploring opportunities to utilize the Research Experience for Undergraduates (REU) program.*
e. *Investigating whether the Sandia Academic Alliance Program, which has a presence on the UTA campus, could offer a graduate student fellowship at WCAPP.*
f. *Participating in the ongoing high-energy-density plasma summer school. This would advertise the work of the Center and provide a great opportunity to recruit postdocs. https://cer.ucsd.edu/events/HEDSSS/index.html.*

g. *Continuing to participate in the annual Omega Laser User Group Workshop. This would provide an opportunity to recruit postdocs.*
h. *Can the Freshman Research Initiative (FRI) be expanded to later years of undergraduate education, so that prospective graduate students are thinking about joining the Center as they apply to graduate schools?*
i. *Can UT Physics Department students, e.g. with a background in spectroscopy, be considered?*
j. *Expand the applicant pool by leveraging the use of more simulations (e.g. with the FLASH code) to attract undergraduate students and graduate students and soften the path to experimental work.*

Finding 6:

An increase in the number of SNL staff participating in WCAPP projects at Z is still desirable, although previous WCAPP researchers have moved into SNL positions and are still involved in Center research. Marc Schaeuble is now an SNL staff member, and Thomas Gomez is now a postdoc at SNL

Recommendation 6:

Reiterating from last year's report: "Investigate applying for any appropriate Laboratory Directed Research and Development (LDRD) funding at SNL and pursue the possibility of creating a 'Z Professorship' that is funded partially by SNL and partially by UT."

3.2. Planning for the Future: year 4 after start and beyond

3.2.1 Broadening part of the focus ("at parameter at Z") to include laser drivers and scaled experiments

This section does, and should, overlap with section 3.1.1, which discusses the next ~2 years research. In particular, in the near term it was recommended that the NIF experiments be fully supported, that new opportunities for experiments be explored at the OMEGA laser facility, Laboratory for Laser Energetics (LLE), University of Rochester (UR), and that experiments on atomic micro-equivalence be considered. Also in that near-term timeframe, WCAPP is encouraged to prepare for opportunities to utilize their white-dwarf results in support of observational data anticipated from the Vera Rubin Large Synoptic Survey Telescope. All these, or more likely a subset, could be a major part of a renewal proposal, and would then extend well into the future considered here. But, while it is always good to have plans for future experiments, the worry is to not spread the existing resources too thinly.

The committee thinks that the concept of micro-equivalence in atomic physics is interesting and could be pursued as a fundamental science experiment. Experiments should be done at the same facility (for instance, at Z or at NIF) to test the idea using the same platform for the "at parameter" experiment and the "scaled experiment."

New ideas for experiments at the OMEGA laser facility were discussed, which would be developed in collaboration with LLE researchers. This would certainly expand the WCAPP capabilities, and probably also help to develop LLE capabilities. Importantly, with current

WCAPP staffing levels, who would lead the experiments? Also, would LLE staff be involved at UT and at the SNL Z experiments? Much remains to be determined.

The top priority here is to develop WCAPP expertise in the atomic and radiation physics of warm- and high-energy-density plasmas, relevant to NNSA. A collaboration with LLE would assist this, and would also expand LLE's capabilities.

Finding 7:

WCAPP should explore in the ~2 year time frame possibilities for new experiments, which will be a part of a renewal proposal

Recommendation 7:

See ***Recommendation 1c, 1d and 1e.***

3.2.2 Strategies for renewal

This section relies heavily on the discussions summarized in the sections above. The Center provides, and must continue to provide:

-World-class research of interest to NNSA/DOE;
-Active and significant participation of academics, graduate and undergraduate students; and
-An introduction of students and postdocs to the research opportunities available at the NNSA laboratories.

It was unanimously agreed that the Center should maintain its focus on the atomic and radiation physics of warm- and high-energy-density plasmas. The recognized challenges of recruiting high-quality postdocs and graduate students in this area require a prioritization of the research, and the committee suggested this prioritization to be (short titles based on the astrophysical objects of interest are used for simplicity):

1) White Dwarf photospheres (including the experiments to be undertaken at NIF that will complement the ongoing experiments on the Z Facility)
2) Solar Opacities
3) Black-Hole Accretion Disks

The third topic (Black-Hole Accretion Disks) will significantly increase in importance with the planned launch of the X-Ray Imaging and Spectroscopy Mission (XRISM) in early 2022. XRISM is likely to renew interest in "reverberation mapping" using X-ray spectroscopy; i.e., observing the response of absorption lines from outflows to changes in the X-ray continuum emission from the central black hole. XRISM will have the effective area and spectral resolution to observe non-equilibrium photoionization (and recombination). Experiments designed to test time-dependent photoionization using the Z facility would be useful.

Finding 8:

(See Finding 1) *The Center is successfully providing world-class research motivated by astrophysics, while addressing problems of interest for stockpile stewardship, Inertial Confinement Fusion (ICF), and High-Energy-Density (HED) physics. This is introducing postdocs and students to unique research opportunities available at the NNSA national security laboratories.*

Recommendation 8:

*(See also **Recommendation 1a**) A successful renewal proposal requires a successful record (research and personnel). The CSAC thinks this is best achieved by maintaining the unique focus on providing world-class, high-fidelity atomic and radiation physics of warm- and high-energy-density plasmas, in particular "at parameter." Positioning for and anticipating renewal, and driven by recruiting challenges, the short-term priority should continue to be the White Dwarf research.*

Finding 9:

Ideas for new research in the near and longer term (see sections 3.1.1 and 3.2.1) include using the lasers at NIF and OMEGA, and the Zebra pinch at UNR. There is an opportunity to investigate scaled atomic physics, the concept of "micro-equivalence." We note that a delay to the NIF experiments is not improbable.

Recommendation 9:

*(See also **Recommendations 1c, 1d and 1e**) A successful renewal proposal requires an exciting plan (research and personnel). Some limited and targeted evaluation of new opportunities is necessary, and limited exploratory studies are warranted. However this must be done without jeopardizing the Center's unique focus and reputation (world-class, high-fidelity atomic and radiation physics of warm- and high-energy-density plasmas, in particular "at parameter"). Data analysis (both of existing Z data and presumed NIF data), and perhaps the NIF experiments themselves, will be a part of the renewal.*

Finding 10:

A successful renewal proposal requires a successful history, proven by metrics. These include not only research metrics (e.g. peer-reviewed papers), but also metrics that address the important objective of training graduate students and postdocs in the specialties of the Center, and exposing them to the capabilities of the NNSA national security laboratories.

***Recommendation10*:**

a. *WCAPP is strongly encouraged to highlight the people it is sending to SNL and other U.S. National Laboratories.*
b. *WCAPP is encouraged to highlight areas in which the Center's work has influenced other institutions and/or investigations.*

3.3 Other areas

3.3.1 Communication

Finding 11:

Maintaining a satisfactory level of communication among the geographically separated participating institutions in WCAPP is challenging yet critical.

Recommendation 11:

The CSAC encourages efforts to improve communication among the Center participants, especially between UT Austin and UN Reno, and between the universities and SNL (and LLNL and the Laboratory for Laser Energetics at the University of Rochester in the future). More frequent visits among participating institutions and the exchange of

personnel among participating institutions are potential ways of improving communication.

4. Final Summary

Here we list the Findings and Recommendations.

Finding 1:

WCAPP is conducting important experiments on the Z Facility and has identified and is pursuing opportunities for additional experiments to study the properties of spectral lines in white dwarf photospheres and envelopes, opacities in the Sun and related stars, and black-hole accretion disks.

Recommendation 1:

a. *WCAPP is strongly encouraged to focus on its Z-pinch experiments to measure the properties of spectra under 1) conditions relevant to white dwarf atmospheres and 2) the opacities of iron under conditions relevant to the interior of the Sun in the next two years.*
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d. *WCAPP is encouraged to investigate the potential utilization of scaled experiments or micro-equivalence in the last year of the current 5-year period of performance of the Center and beyond.*
e. *WCAPP is encouraged to prepare for opportunities to utilize their white-dwarf results in support of the flood of observational data anticipated from the Vera Rubin Observatory (formerly the Large Synoptic Survey Telescope).*

Finding 2:

Continuing to provide a pool of graduate students and postdocs trained in the atomic and radiation physics of warm- and high-energy-density plasmas, from which the National Laboratories can seek to recruit staff, is an important goal of WCAPP.

Recommendation 2:

WCAPP is strongly encouraged to continue to train graduate students and postdocs in undertaking experiments, theory and numerical simulations of atomic physics experiments, and in so doing, to expose them to the facilities and the work in this area at the NNSA national security laboratories.

Finding 3:

The research of the WCAPP team on Z, performed in collaboration with staff from SNL, LLNL, and LANL, is likely to continue to produce outstanding scientific results. While the UT proposals to the Z Fundamental Science Program (ZFSP) continue to be highly rated and approved for experimental time on Z, the UNR proposals need to be strengthened to be competitive.

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c. *Stay disciplined with respect to physics focus and shot selection.*
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e. *Always remember that the Z Facility is not a national user facility (and all that this situation entails).*

Finding 4:

A number of plasma and spectral modeling tools are currently in use and available for analysis of the various plasma spectroscopy experiments being conducted. There was not unanimity on the priority of utilizing the FLASH code. Depending on the committee member, high-fidelity validated numerical simulations (3-dimensional) either "are essential" or "can be useful " for interpreting the results.

Recommendation 4:

The main deficiency in this area is the shortage of personnel in the center to make full use of these tools. Depending on the committee member:

Either:

a. *If manpower shortages are alleviated, and if a suitable student or students become available, another attempt to utilize the FLASH code should be made.*

Or:

b. *WCAPP is strongly encouraged to conduct high-fidelity, validated numerical simulations of past and future experiments using, e.g., the FLASH code.*
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Finding 5:

Recruiting and hiring graduate students is of highest priority, and this requires making undergraduates and graduate students more aware of the research opportunities offered by WCAPP.

Recommendation 5:

Options for enhancing the recruitment of graduate students and postdocs include (with some questions):

a. *A great website*
b. *Information near the entrance to the RLM building on the UT Austin campus.*
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h. *Can the Freshman Research Initiative (FRI) be expanded to later years of undergraduate education, so that prospective graduate students are thinking about joining the Center as they apply to graduate schools?*
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j. *Expand the applicant pool by leveraging the use of more simulations (e.g. with the FLASH code) to attract undergraduate students and graduate students and soften the path to experimental work.*

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An increase in the number of SNL staff participating in WCAPP projects at Z is still desirable, although previous WCAPP researchers have moved into SNL positions and are still involved in Center research. Marc Schaeuble is now an SNL staff member, and Thomas Gomez is now a postdoc at SNL.

Recommendation 6:

Reiterating from last year's report: "Investigate applying for any appropriate Laboratory Directed Research and Development (LDRD) funding at SNL and pursue the possibility of creating a 'Z Professorship' that is funded partially by SNL and partially by UT."

Finding 7:

WCAPP should explore in the ~2 year time frame possibilities for new experiments, which will be a part of a renewal proposal.

Recommendation 7:

See ***Recommendation 1c, 1d and 1e.***

Finding 8:

*(**See Finding 1**) The Center is successfully providing world-class research motivated by astrophysics, while addressing problems of interest for stockpile stewardship, Inertial Confinement Fusion (ICF), and High-Energy-Density (HED) physics. This is introducing postdocs and students to unique research opportunities available at the NNSA national security laboratories.*

Recommendation 8:

*(See also **Recommendation 1a**) A successful renewal proposal requires a successful record (research and personnel). The CSAC thinks this is best achieved by maintaining the unique focus on providing world-class, high-fidelity atomic and radiation physics of warm- and high-energy-density plasmas, in particular "at parameter." Positioning for and anticipating renewal, and driven by recruiting challenges, the short-term priority should continue to be the White Dwarf research.*

Finding 9:

Ideas for new research in the near and longer term (see sections 3.1.1 and 3.2.1), include using the lasers at NIF and OMEGA, and the Zebra pinch at UNR. There is an opportunity to investigate scaled atomic physics, the concept of "micro-equivalence." We note that a delay to the NIF experiments is not improbable.

Recommendation 9:

*(See also **Recommendations 1c, 1d and 1e**) A successful renewal proposal requires an exciting plan (research and personnel). Some limited and targeted evaluation of new opportunities is necessary, and limited exploratory studies are warranted. However this must be done without jeopardizing the Center's unique focus and reputation (world-class, high-fidelity atomic and radiation physics of warm- and high-energy-density plasmas, in particular "at parameter"). Data analysis (both of existing Z data and presumed NIF data), and perhaps the NIF experiments themselves, will be a part of the renewal.*

Finding 10:

A successful renewal proposal requires a successful history, proven by metrics. These include not only research metrics (e.g. peer-reviewed papers), but also metrics that address the important objective of training graduate students and postdocs in the specialties of the Center, and exposing them to the capabilities of the NNSA national security laboratories.

Recommendation10:

a. *WCAPP is strongly encouraged to highlight the people it is sending to SNL and other U.S. National Laboratories.*
b. *WCAPP is encouraged to highlight areas in which the Center's work has influenced other institutions and/or investigations.*

Finding 11:

Maintaining a satisfactory level of communication among the geographically separated participating institutions in WCAPP is challenging yet critical.

Recommendation 11:

The CSAC encourages efforts to improve communication among the Center participants, especially between UT Austin and UN Reno, and between the universities and SNL (and LLNL and the Laboratory for Laser Energetics at the University of Rochester in the future). More frequent visits among participating institutions and the exchange of personnel among participating institutions are potential ways of improving communication.

Appendix 1 Meeting Agenda

I. Welcome by Chair, Volker Bromm (8:30 – 8:40)

II. Introduction to Meeting by Chair of CSAC, Alan Wootton (8:40 – 8:50)

III. Introduction to WCAPP (Don Winget) (8:50 – 9:50)
   a. Why WCAPP, and what defines success
   b. Finishing year 2. What has changed in the last year, particularly in response to the CSAC 2019 report?
   c. Three general areas where advice is requested from the committee: science in the years 3-5, personnel needed to achieve these science goals, and longer-term science ideas that need exploratory studies in the 2- to 3-year time frame. Renewal strategies.

IV. Evolving Relation of WCAPP to Sandia (Jim Bailey) (9:50 – 10:00)

V. Highlights of current experiments and modeling finishing 2 years and leading to years 3–5 (10:00 – noon)
   a. Opacities in the Sun and related stars (Jim Bailey)
   b. Atomic physics and x-ray heating of photoionized plasmas (Roberto Mancini)
   c. White dwarf photospheres and theoretical developments (Bart and Mike Montgomery)
   d. Black hole accretion disc radiation (Guillaume Loisel)
   e. Plans for NIF (motivations and time-frames) and other platforms (Mike & Don)
   f. Recent Results from HETDEX Survey (Ben Thomas) (12:00 – 12:15)

LUNCH (catered), time to stretch/walk (12:15 – 1:15)

VI. Discussions with CSAC (CSAC, PIs, and Co PIs) (1:15 – 2:45)
Focus Questions for the discussion:
   a. Years 3-5: Is the proposed research that is focused around the Z facility at SNL (physics and astrophysics, experiment and theory, and tools) unique, world class, likely to be approved for time on Z, and likely to succeed?
   b. Is the research planning, especially human effort (including postdocs, students, additional institutions) adequate for success?
   c. Looking to year 4 and beyond, are there any exploratory studies we should be undertaking in the 2- to 3-year time frame? Is it the right time to be evaluating what could be done not only "at parameter on Z" but also on lasers, and including scaled experiments?
   d. Strategies for renewal.

VII.	CSAC meets alone	(2:45 – 4:00)
VIII.	OUTBRIEF to PI and Co PIs	(4:00 – 4:30)

4:30pm adjourn

Link to the Wootton Center for Astrophysical Plasma Properties:
https://wcapp.astronomy.utexas.edu/

Wootton Center for Astrophysical Plasma Properties
Center Scientific Advisory Committee

Nancy Brickhouse	Date
Chris Fontes	Date
David Kilcrease	Date
Don Lamb	Date
Keith Matzen	Date
Marilyn Schneider	Date
Hugh Van Horn	Date
Alan Wootton, Chair	Date