Impact Analysis:
AIP Proceedings of the 7th, 8th and 9th International Temperature Symposia

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1.0 Introduction

The International Temperature Symposium (ITS) is a conference coordinated and sponsored by NIST every ten years. The proceedings are published by the American Institute of Physics (AIP) as a recurring volume entitled "Temperature: Its Measurement and Control in Science and Industry." As the conference is held so infrequently, it competes with more regular venues for papers and researcher participation and attendance. The purpose of this analysis is to evaluate the impact and value of participating in the Symposium and to update previous related analyses.

To assess the impact of the ITS, ISO reviewed citation data from 616 papers from the 1992 (7^{th}), 2002 (8^{th}) and 2013 (9^{th}) conferences. The most significant measure of impact is the citation patterns for these papers. ISO examined and analyzed this data to determine:

- International reach: Which institutions from which countries cite papers presented at the symposium? (Section 3.1)
- Durational relevance: How many times have ITS papers been cited? How has that citation pattern changed as a function of time, given the infrequency of the conference itself? (Section 3.2)
- Breadth of coverage: What is the range of subject areas addressed in the citing papers? How broadly do ITS papers apply and extend into other areas? (Section 3.3)
- Citing publication prestige: How prestigious are the journals and venues in which ITS citing papers are published? (Section 3.4)

Results of ISO's analysis indicate the following findings:

- 616 original conference papers have been published in three proceedings: 238 in 1992 (7^{th}), 191 in 2003 (8^{th}), and 189 in 2013 (9^{th}). These 616 papers were cited a total of 2218 times (2016 without self-citations) in 1375 new articles (1263 without self-citations).
- The h-index for these 616 papers is 18; this indicates that 18 articles have each been cited 18 or more times. The average citations per item is 3.59.
- Citation patterns remain relatively consistent over the course of the decade between occurrences of the 7^{th}, 8^{th} and 9^{th} international conferences. They have not diminished over time, demonstrating value and impact.
- More than 500 organizations from 55 separate countries have published articles citing the papers from ITS proceedings. These organizations encompass a variety of settings from national metrology institutes (NMIs), research universities, publicly funded government research centers and private companies.
- 51 individual journals have published 3 or more articles in which ITS authors' work have been cited. The impact factors for these journals ranges from 20.113 (*Nature Physics)* to 0.140 (*Measurements Control)*. The median impact factor for this collection of journals is 2.438.
- An additional 158 journals have published 2 or less articles citing ITS authors' papers.

2.0 Methodology

A journal's impact factor is defined by Thomson-Reuters as "a measure of the frequency with which the 'average article' in a journal has been cited in a particular year or period." Conference proceedings are not assigned quantifiable metrics in the same way as journals; there are no equivalent impact factors for a conference title as there are for individual journal titles. Even for journals, impact factor is only one measure of prestige and impact and only has meaning when compared with journals in the same subject area. It would be imprudent to rely solely on a journal's impact factor to assess the value of publishing within that title.

The data sets for the analysis discussed in this report were created using Clarivate's *Web of Science* and *Journal Citation Reports* database products. *Web of Science* is a well-defined bibliographic database that indexes more than 10,000 scientific, peer-reviewed journals and selected conference proceedings. *Web of Science* describes their conference proceeding selection process as [Clarivate]:

> "Each year the worldwide community of scholars and the professional societies to which they belong organize tens of thousands of meetings at which the members present papers on their latest research. The conference proceedings issued at these gatherings are published as items in journals or as books. From this vast body of literature, *Web of Science* selects for coverage in its Conference Proceedings Citation Index (CPCI) only those publications which will be of greatest importance to the largest number of researchers and scientists worldwide."

The inclusion of ITS papers within this subset of *Web of Science* conference proceedings is, in and of itself, an indicator of impact, particularly for a conference held only once every ten years.

Web of Science was selected for this analysis to determine the rate at which ITS papers are cited within other articles. Citations are a measure of how a research community views the quality and prestige of the conference and its resulting proceedings.

The *Journal Citation Reports (JCR)* is an annual publication that collects data on the scholarly journals published in the science and social sciences. The *JCR* provides a relative measure of journal prestige through the parsing of citation metric data over time in order to determine citation patterns for individual journal titles over a variety of subject categories. *JCR* tracks more than 9000 journal titles in more than 230 subject disciplines. The *JCR* is the acknowledged resource for finding a journal title's Impact Factor (IF) over time as well as the subject categories that an individual journal title covers.

The analysis for this report focused on papers from the 7th, 8th and 9th ITS events as they provided the timeliest examples of the Symposia's output. These three conferences produced 616 individual papers which were cited by 1375 articles. This collection of 1375 articles comprise the basic data set used for this analysis.

Using various features of *Web of Science,* the basic data set was then mined for the following information:

- Institutions authoring these citing articles and the countries where they are located
- Impact factors for the journals where citing articles have been published
- Range of subject categories for the citing articles
- Citation rates over time for these articles

3.0 Results

The 616 papers published in ITS have been cited more than 2200 times by 1375 individual articles. Of those citing publications, two-thirds were published as journal articles. Figure 1 shows the percentage distribution of publication type for these citing articles. This collection of 1375 publications comprises the dataset used for this analysis.

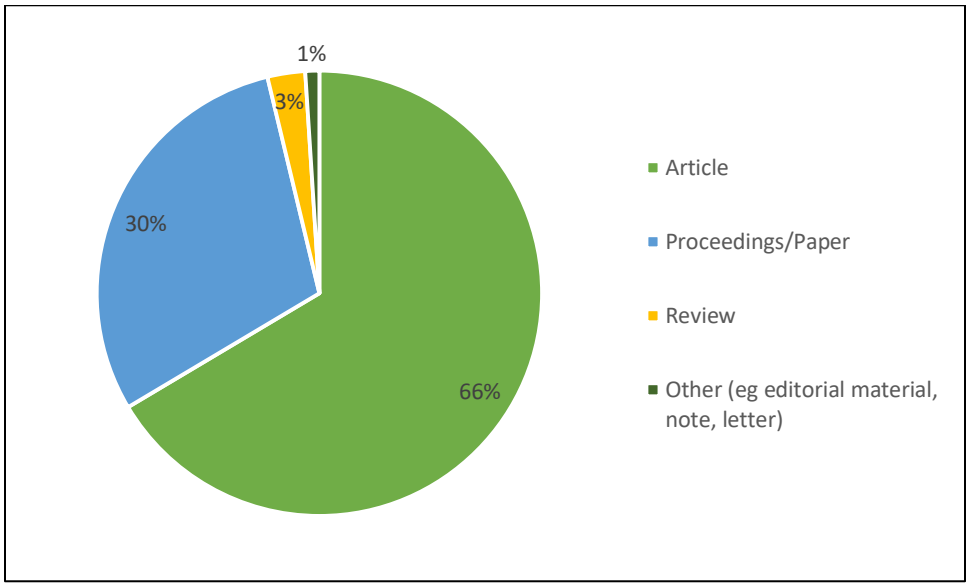

Figure 1. Document types of citing papers for compilation of 7th, 8th and 9th ITS conferences

From this dataset, 47 unique institutions have cited 10 or more ITS papers and another 63 organizations have cited between 5 and 9 papers from the most recent ITS conferences held in 1992, 2002 and 2013. These institutions represent a diverse geographic span. Figure 2 illustrates the 30 countries which have cited 10 or more ITS papers.

The United States (US) has cited ITS papers more than 300 times, which is consistent given the size of the country and the breadth of its academic and research institutions. Several European countries have consistently cited ITS papers over the last three conferences. These include England (181), Germany (175), Italy (146) and France (101). Other countries such as Japan (184), China (168) and Russia (73) have also cited many ITS papers. However, it is notable that the geographic "reach" of ITS research findings has expanded into areas such as New Zealand (71), South Korea (49), Australia (31), Turkey (23) and Egypt (17).

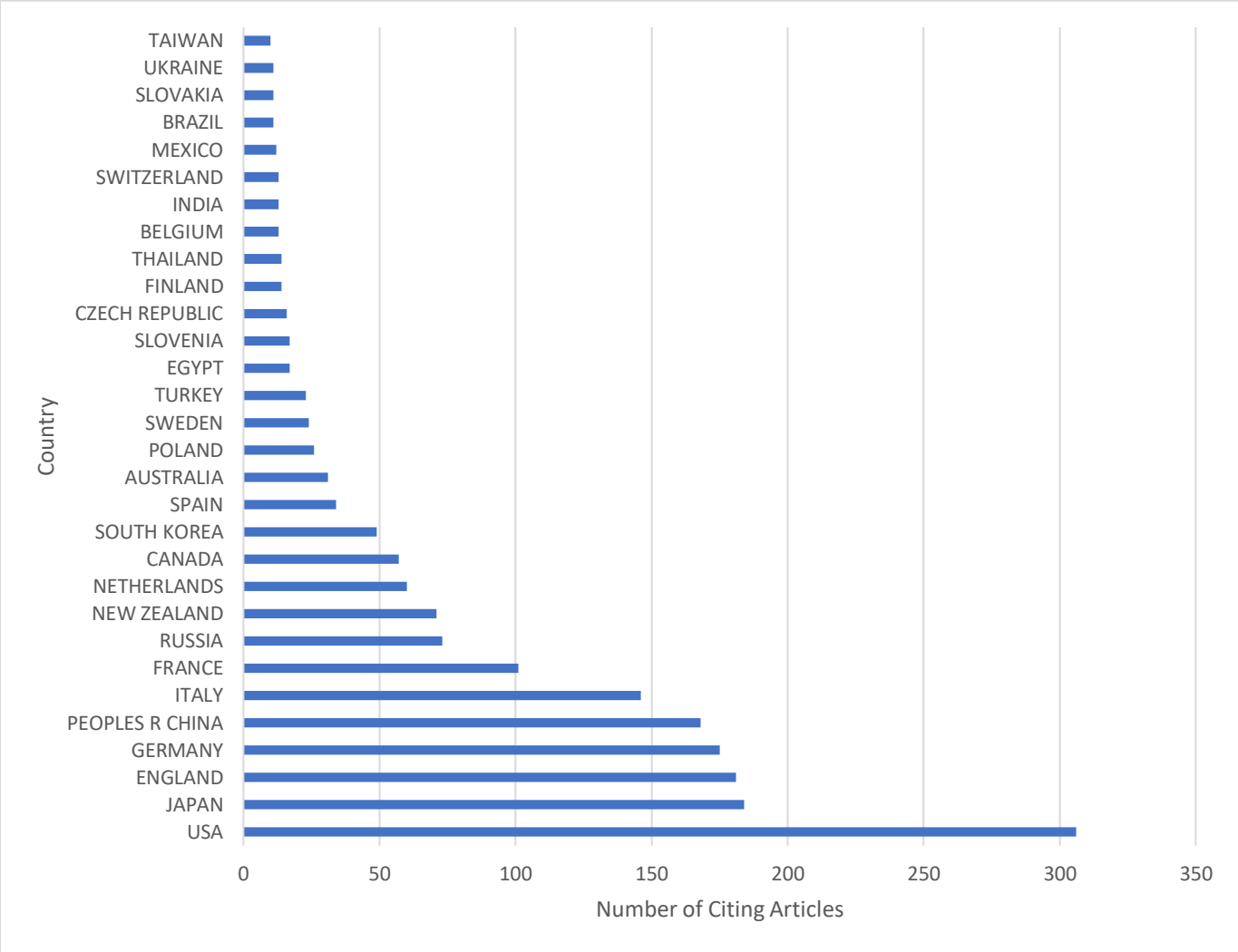

Figure 2. Number of citing publications by country

3.1 Organizations and Institutions

Table 1 illustrates the National Metrology Institutes (NMI) that have published five or more articles citing ITS research from the 7th, 8th and 9th conferences. Previous analysis of the 7th and 8th conferences indicated that five NMIs had published multiple articles citing ITS research. These NMI represented the US, Germany, UK, Korea and China. Since the 9th conference in 2013, it is significant to note that the collection of NMI citing ITS research has grown from 5 to 13 organizations. In addition, the geographic diversity of these institutions has expanded to include NMI from countries such as New Zealand, Netherlands, Thailand, Mexico and Brazil. This suggests the impact of ITS publications on other international metrology programs.

Table 1. National Metrology Institutes (NMI) publishing five or more articles citing ITS research, listed by magnitude of publications

National Metrology Institutions	Country
NIST	US
National Research Laboratory (NPL)	UK
National Metrology Institute of Japan (NMIJ)	Japan
Instituto Nazionale Di Ricerca Metrologica (INRIM)	Italy
Physikalish-Technische Bundesantaslt (PTB)	Germany
National Institute of Metrology (NIM)	China
Measurement Standards Laboratory (MSL)	New Zealand
Korea Research Institute of Standards Science (KRISS)	Korea
Dutch Metrology Institute (VSL)	Netherlands
National Institute of Metrology	Thailand
National Measurement Institute (NMI)	Australia
Centro Espanol de Metrologia (CEM)	Spain
National Metrology Institute of Turkey (UME)	Turkey
Centro Nacional de Metrologia (CENAM)	Mexico
Slovak Institute of Metrology (UNMS SR)	Slovakia
Czech Metrology Institute	Czech Republic
D.I. Mendeleev Institute for Metrology (VNIIM)	Russia
National Institute of Metrology Standardization and Industrial Quality (INMETRO)	Brazil

Table 2 displays the universities and academic institutions citing five or more ITS articles, listed in order of magnitude of publications. As would be expected, the US has a significant number of academic institutions represented with a total of eight universities or university systems. For example, the University of California system had researchers from three separate campuses publish articles citing ITS authors. There are other countries with publications from multiple institutions including China, France, UK, Japan and Germany. The remaining universities are from a wide range of geographic areas including Netherlands, Sweden, Slovenia, Poland, Italy, Austria, India and Singapore. The array of academic institutions citing ITS research has expanded considerably since the 9th conference took place in 2013, suggesting that the ITS conferences remain valuable for their participants.

Table 2. Universities publishing five or more articles citing ITS articles research, listed by magnitude of publications

University	Location
National Conservatory of Arts and Crafts (CNAM)	France
Hesam Universite	France
University of California system/UC Davis/UC Berkley/UC Santa Barbara	US
Henan Normal University	China
Toyo University	Japan
University of Ljubljana	Slovenia
Beijing University of Technology	China
Leiden University	Netherlands
Lund University	Sweden
Harbin Institute of Technology	China

State University system of Florida/University of Florida	US
Stanford University	US
University of Sheffield	UK
Polish Academy of Sciences	Poland
Chiba University	Japan
City University London	UK
Universite Paris Saclay	France
Technical University of Berlin	Germany
University of Chinese Academy of Sciences (CAS)	China
University of Erlangen-Nuremberg	Germany
University of New Mexico	US
University of Turin	Italy
Graz University of Technology	Austria
Indian Institute of Technology System	India
Purdue University	US
Shanghai Jiao Tong University	China
Tsinghua University	China
University of Chicago	US
University of Colorado System/UC Boulder	US
University of London	UK
Virginia Polytechnic Institute State University	US
Beijing University of Chemical Technology	China
China Jiliang University	China
Ecole Polytechnique Federale de Lausanne	France
National University of Singapore	Singapore
Ritsumeikan University	Japan
Royal Holloway University London	UK
Universite de Toulouse	France
University of Bayreuth	Germany
University of Oxford	UK
University of Tokyo	Japan
University of Twente	Netherlands

The public institutions and government labs publishing five or more articles citing ITS research are displayed in Table 3. Organizations from more than a dozen different countries are represented in this collection. This includes larger countries such as China, Russia, France and Germany. However, as noted previously with universities and NMIs, the “reach” of ITS publications has expanded to include government labs in new regions of the world including Australia, New Zealand, Italy, Turkey, Spain, Japan and Ukraine. This suggests marked growth of the impact of this conference.

Table 3. Public institutions or government labs publishing five or more articles citing ITS articles research, listed by magnitude of publications

Institution	Location
National Institute of Advanced Industrial Science and Technology (AIST)	Japan
Consiglio Nazionale delle Ricerche (CNR)	Italy
National Research Council (NRC)	Canada
Department of Energy (DOE)	US
Laboratoire National de Metrologie et D'Essais (National Laboratory of Metrology and Testing)	France
Callaghan Innovation	New Zealand
Centre National de la Recherche Scientifique – CNRS (French National Center for Scientific Research) • CNRS Institute for Engineering Systems Sciences • CNSR Institute for Physics	France
Russian Academy of Sciences	Russia
NASA/NASA JPL	USA
Chinese Academy of Sciences	China
Helmholtz Association	Germany
Turkiye Bilimsel Ve Teknolojik Arastirma Kurumu – TUBITAK (Scientific and Technological Research Council of Turkey)	Turkey
Joint Institute for High Temperatures of the Russian Academy of Sciences (JIHT)	Russia
European Commission Joint Research Centre (JRC)	Italy
Los Alamos National Laboratory (LANL)	US
All-Russian Research Institute for Optical and Physical Measurements Federal State Unitary Enterprise (VNIIOFI)	Russia
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	Australia
Technical Institute of Physics and Chemistry of the Chinese Academy of Sciences (TIPC-CAS)	China
Commissariat a L'energie Atomique (CEA)	France
Consejo Superior de Investigaciones Cientificas – CSIC (Spanish National Research Council)	Spain
Argonne National Laboratory (ANL)	US
European Commission Joint Research Institute for Transuranium Elements (ITU)	Germany
Japan Aerospace Exploration Agency (JAXA)	Japan
National Academy of Sciences of Ukraine	Ukraine
Oak Ridge National Lab (ORNL)	US
Lawrence Berkeley National Laboratory (LBNL)	US
Sandia National Laboratory (SNL)	US

Several private companies have published research citing ITS article more than five times. These companies encompass a variety of sectors including maritime industries, climatological research, cryogenics, instrumentation, control systems, materials testing, optical fibers, and lasers. These companies are listed in Table 4.

Table 4. Private institutions or corporations publishing five or more articles citing ITS articles research, listed by magnitude of publications

Institution	Location
Leibniz Institut fur Ostseeforschung Warnemunde (Leibniz Institute for Baltic Sea Research)	Germany
Chino Corporation	Japan
Lake Shore Cryotronics Inc	USA
Advanced Engineering Services Co Ltd	Japan
Rotech Labs	UK
SRI International	US

3.2 Citation Patterns and Durational Relevance

For a conference that is held once every ten years, it is useful to analyze the citation patterns over time for the papers presented. The main question addressed through this analysis is "do the papers still hold value and relevance for a technical audience if they are part of an infrequent conference?" To answer this question, we consider the number of citations per year from 1993 to the present. The combined results for the 7th, 8th and 9th ITS conferences are shown in Figure 3.

Citation quantity is a multi-faceted issue, which considers such factors as the size of a specific subject area, the number of researchers in that area and the quantity of publication venues for a given research topic. The patterns illustrated in Figure 3 validate a consistent interest in ITS papers over time. Cumulatively over the time span covering the 7th conference (1993) through present, the median citations per year is 76.5. The mean number of citations over the same time span is 78.9. In 2011 when this analysis was performed for the 7th and 8th ITS conferences only, the median citations per year was 35 and the mean citations per year was 39. Even accounting for the publication of the 9th ITS proceedings in 2013, this is still a substantial increase as these citations are attributed to papers from all three conferences. The quantity of citations, in and of itself, is less meaningful than the consistent citations from year to year, still averaging more than 75. The passage of time has not reduced the interest in papers published in the 7th and 8th ITS proceedings.

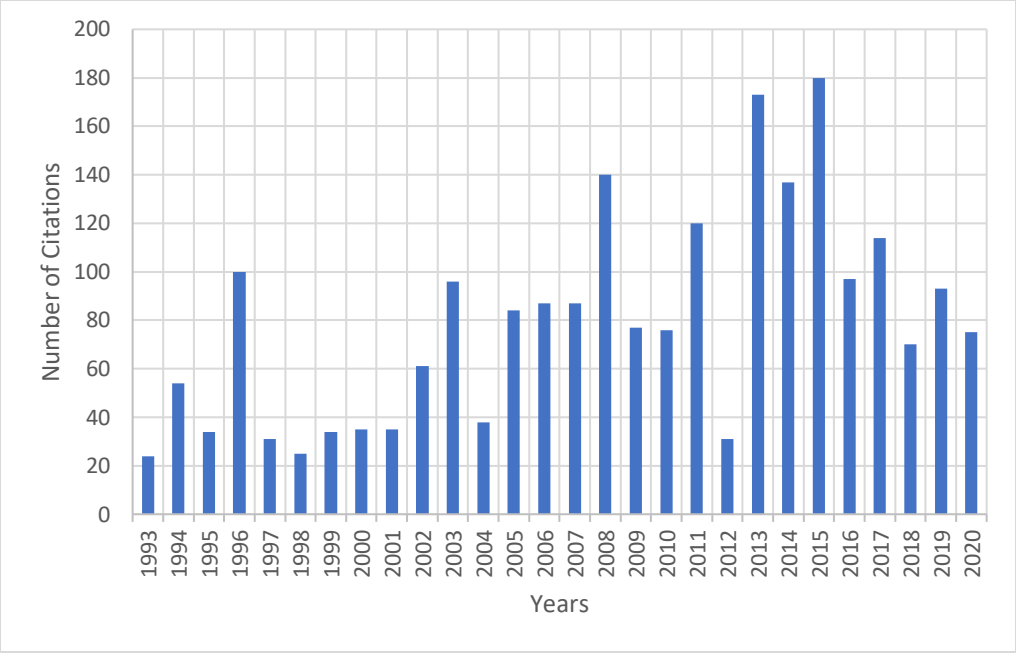

Figure 3. Combined citation patterns over time for ITS papers from 1992, 2002 and 2013 conferences

Figure 4 illustrates the citation pattern for the 7th ITS conference, held in 1992. This conference produced 238 papers which have been cited 873 times in 619 separate articles. Papers from this conference are still being cited well into 2020, showing very strong durational relevance for a conference held nearly 30 years ago. The citation peak in 2003 likely corresponds to additional citations of 7th ITS conference papers within publications in the 8th ITS conference held in 2002.

The peak of 100 citations in 1996 is attributed to 52 publications from several NMI's including NIST, UK's NPL, Germany's PTB, and France's BIPM. The remaining citations are distributed amongst several other countries including Canada, Italy, Sweden, South Korea, Japan and Mexico. It is particularly noteworthy that five citations are attributed to private companies headquartered in the US. This suggests that US researchers publishing in ITS proceedings are likely to impact American-based businesses.

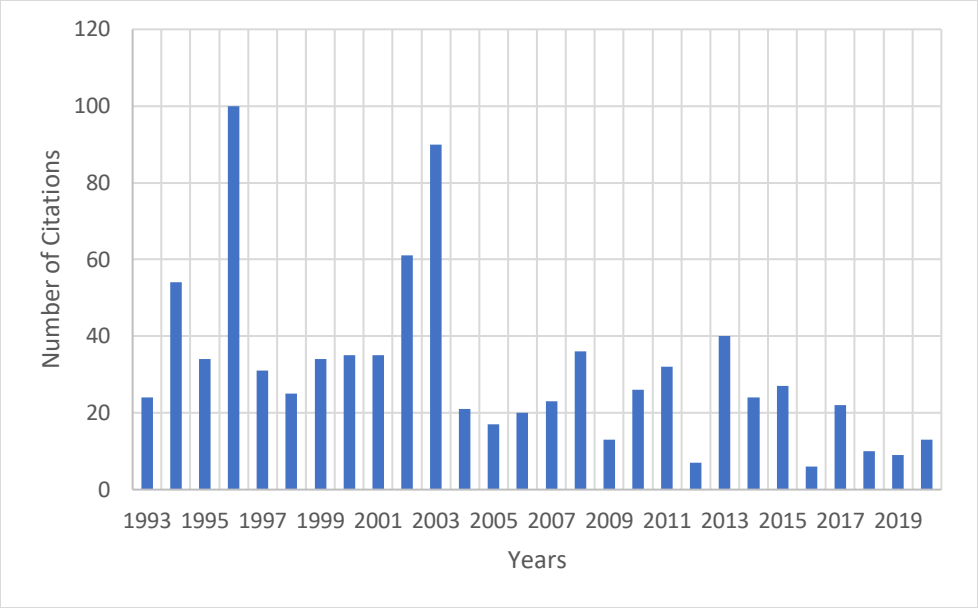

Figure 4. Citation patterns over time for 7th ITS Conference, from 1993-present

The 8th ITS conference proceedings, published in 2003, included a total of 191 papers which have been cited 896 times in 631 papers. Three peaks in citation patterns are noted in 2008, 2011, and 2013, as shown in Figure 5. The increased citations in 2013 are likely attributable to 8th ITS conference papers cited within 9th ITS conference publications.

The citation spikes in 2008 and 2011 bear further investigation. In 2008, most of the increased citation activity was due to research at various NMI's across the world: NIST/US, Japan, UK, China, and Germany. In addition, five citing papers were authored by researchers at private corporations, in collaboration with NIST or academia. Once again, this indicates that publications in ITS proceedings creates "ripple effects" into the US economy via teaming with business or academic partners. The citation increases in 2011 were primarily due to research activity at NMI's from Japan, China, Germany and UK with additional research progress in Japan's government labs.

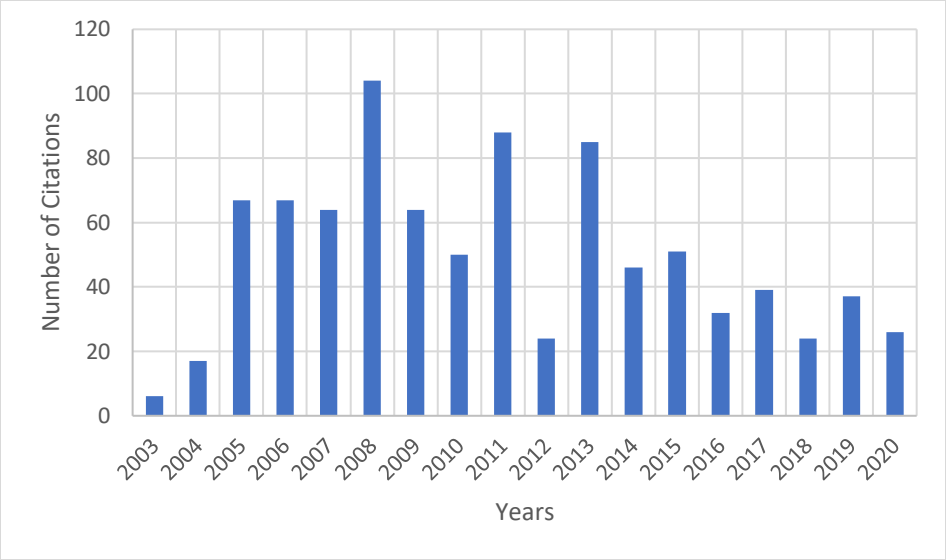

Figure 5. Citation patterns over time for 8th ITS Conference, from 2003-present

Figure 6 shows the citation patterns over time for the 187 papers published as part of the 9th ITS in 2013. These papers have been cited a total of 449 times by 322 articles to date. In 2015, papers from the 9th ITS conference were cited 102 times within 67 separate articles. The researchers responsible for these citing articles were primarily from NMIs in UK, Japan, China, Italy, and Germany.

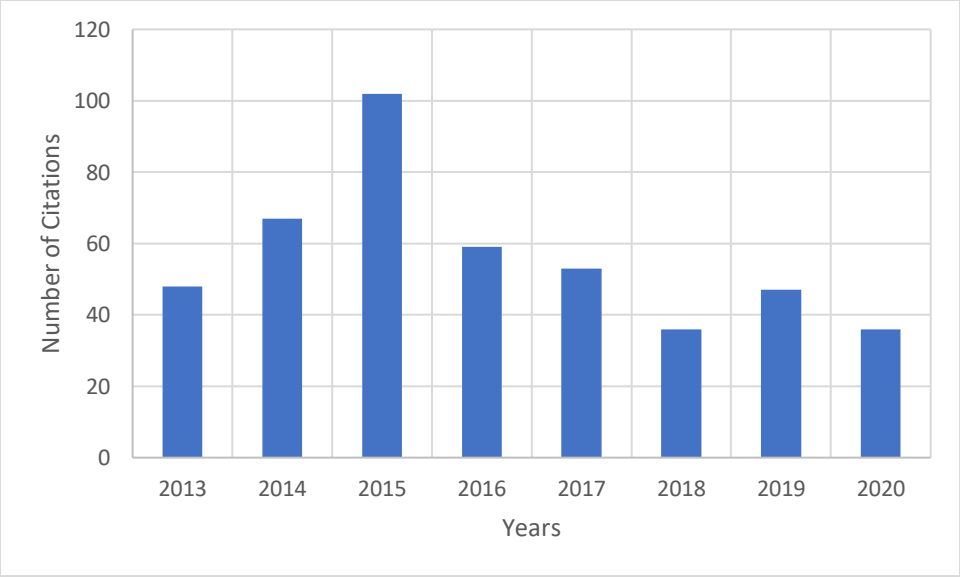

Figure 6. Citation patterns over time for 9th ITS Conference, from 2013-present

3.3 Subject Matter Breadth

Within *Web of Science,* articles can be assigned multiple subject categories by the database's indexing staff. Figure 7 represents those subject categories assigned to ten or more citing papers. The breadth of assigned subject categories ranges from applied physics

thermodynamics to energy fuels and robotics. Other subject categories with ten or less citing papers include multidisciplinary chemistry, engineering manufacturing, materials science ceramics, nuclear science technology, computer science methods, crystallography, spectroscopy, geosciences, telecommunications and environmental sciences. This demonstrates the breadth of application for research published in ITS proceedings.

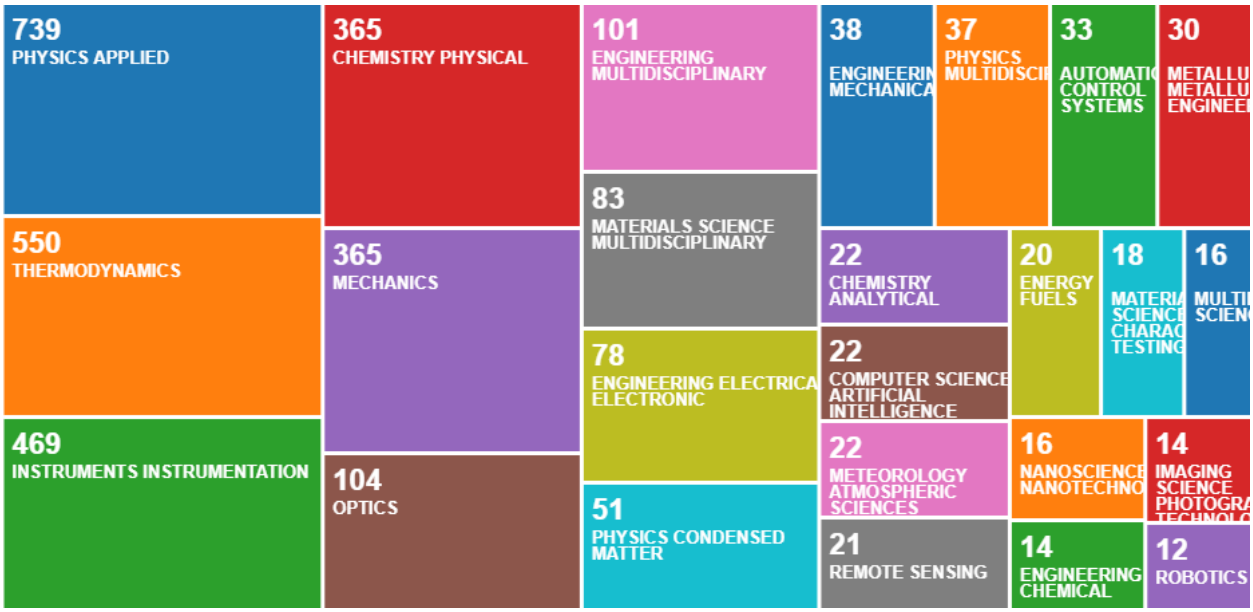

Figure 7. Subject categories for publications citing ITS papers

3.4 Citing Journals and Conferences

Articles which have cited ITS conference papers have been published in a wide range of journals. Table 5 provides the list of journal titles and their corresponding Impact Factor (IF) for all titles in which ITS papers have been cited three of more times. The median value for IF within this collection of journals is 2.436, from a range of 20.113 to 0.14. Removing the three articles from *Nature Physics* still yields a median IF value of 2.328. In 2011, when this analysis was last performed for 7th and 8th ITS conferences, the median value for IF of citing journal titles was 1.537. This indicates a significant increase in the prestige of journals citing ITS research output.

Table 5. Impact factors of journals citing ITS papers three or more times, compiled for 7th, 8th and 9th ITS conferences

Journal Title	Impact Factor	Times Citing ITS Articles
Nature Physics	20.113	3
Physical Review Letters	9.227	5
International Journal of Heat and Mass Transfer	4.346	10
Journal of Materials Processing Technology	4.178	3
Journal of Alloys and Compounds	4.175	5
Combustion and Flame	4.120	3

Applied Thermal Engineering	4.026	3
Physical Review B	3.736	6
International Journal of Climatology	3.601	3
Optics Express	3.561	4
Metrologia	3.447	168
Journal of the American Ceramic Society	3.094	6
Philosophical Transactions of the Royal Society A Mathematical Physical and Engineering Sciences	3.093	7
IEEE Sensors Journal	3.076	6
IEEE Transactions on Instrumentation and Measurement	3.067	8
Sensors	3.031	7
Journal of Chemical Physics	2.997	3
Physical Review A	2.907	4
Journal of Raman Spectroscopy	2.809	4
Measurement	2.791	14
Sensors and Actuators A Physical	2.739	7
Calphad Computer Coupling of Phase Diagrams and Thermochemistry	2.652	6
Journal of Physics Condensed Matter	2.595	3
Journal of Nuclear Materials	2.547	6
Journal of Applied Physics	2.328	10
Infrared Physics Technology	2.313	11
Journal of Chemical Thermodynamics	2.290	9
Thermochimica Acta	2.251	5
Applied Optics	1.973	17
Physica B	1.874	7
Measurement Science and Technology	1.861	48
Applied Physics B Lasers and Optics	1.769	10
Review of Scientific Instruments	1.587	35
Journal of Crystal Growth	1.573	6
Journal of Low Temperature Physics	1.491	21
Japanese Journal of Applied Physics	1.471	4
Cryogenics	1.336	14
Mapan Journal of Metrology Society of India	1.250	4
Optical Engineering	1.209	3
High Temperature	1.164	3
Journal of Research of the National Institute of Standards and Technology	1.105	8
Metrology and Measurement Systems	1.096	3
International Journal of Thermophysics	0.853	314
Czechoslovak Journal of Physics	0.574	4
High Temperatures High Pressures	0.431	6
Heat Transfer Research	0.398	4
Measurement Techniques	0.390	18
Measurements Control	0.140	3

In addition to the citing journal articles, there are 468 conference papers which have also cited ITS papers. 204 of these 468 papers are also simultaneously classified as journal articles. For the remaining 264 articles designated solely as proceedings papers, the most frequent venues include ITS and the Symposia on Temperature and Thermal Measurements in Industry and

Science (TEMPMEKO). ITS papers have also been cited at conferences with subject coverage including:

- Advanced materials research
- Combustion
- Control automation
- Cryogenics
- Electrical and power engineering
- Electromagnetic measurements
- Energy
- Environmental sensing
- High speed photography and photonics
- Intelligent systems design
- Laser 3D manufacturing
- Manufacturing and design science
- Mathematics for applied sciences
- Medical measurements and applications
- Metals processing
- Nuclear instrumentation and measurement
- Optical spectroscopy
- Remote sensing
- Satellite data compression
- Sensor systems
- Thin-film compound semiconductor photovoltaics

4.0 Conclusions and Recommendations

The results of this analysis indicate the following observations regarding papers submitted to and presented at the International Temperature Symposia:

- Citation patterns are significant and relatively robust over time, which is notable particularly for a conference given only once every ten years. For example, papers from the 7th ITS conference have generated 13 citations in 2020 as of early July. This is meaningful for a conference which took place nearly 30 years ago.
- Subject breadth coverage for citing articles is broad, indicating a wide applicability and influence for the papers.
- Median impact factor of 2.438 for journal titles is significant, particularly given the range of subject coverage within this collection of titles and represents a marked increase over the equivalent metric for previous conference analysis.
- The quantity of international researchers who have cited ITS papers is both substantial and diverse, indicating a depth of “reach” for the proceedings. This is particularly noteworthy when compared to the findings of the 2011 analysis of the 7th and 8th ITS conferences.

- The variety of institutions, ranging from national metrology institutes to academia to corporate entities, citing ITS papers has also expanded since the 2011 analysis report. This emphasizes the impact of the conference as more organizations find value and applicability in ITS research findings.

5.0 References

Clarivate Web of Science. “Web of Science conference proceedings selection process.” https://clarivate.com/webofsciencegroup/essays/web-science-conference-proceedings-selection-process/ Accessed 8/10/2020.