ENGINEERING EXCELLENCE AND THE ROLE OF TECHNICAL STANDARDS

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Various endeavors are undertaken to ensure engineering excellence. Determining how to measure and ascertain the degree to which engineering excellence has been achieved is another matter. The Columbia Space Shuttle accident in February 2003 brought additional visibility within NASA to the subject of engineering excellence. In response to the Columbia Accident Investigation Report, NASA implemented an independent Technical Authority for technical requirements and processes directly affecting the safe and reliable operation of NASA products and missions. This technical authority was delegated to Discipline and Systems Technical Warrant Holders. Technical standards were integral to the Discipline Technical Warrant Holders responsibilities. In this regard, the NASA Technical Standards Program worked in close collaboration with the independent Technical Authority. With the thrust to enhance engineering excellence within the Agency in response to the Administrator's initiative, technical standards were also noted as an important element of engineering excellence. This paper addresses the role of technical standards with regard to enhancing engineering excellence as part of this process.

I. ENGINEERING EXCELLENCE

Engineering excellence is the goal of all engineering organizations, whether government or private industry, national or international. What do we mean by engineering excellence? While most people have their own ideas and interpretation as to what constitutes engineering excellence, perhaps a good place to start would be by defining the terms. According to "Mr. Webster" engineering is defined as the application of scientific and mathematical principals to practical ends such as the design, construction, and operation of efficient and economical structures, equipment, and systems. Excellence is defined as the state, quality, or condition of excelling;

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superiority, with excel being defined as to be better than; surpass---to surpass or do better than others. We believe most, if not all, people would be comfortable with these definitions.

Taking these definitions as a start, the question arises as to how one will recognize or otherwise measure “excellence”.. In this regard, we would like to paraphrase a remark of Louis Armstrong about jazz music that was referenced by the NASA Administrator, Michael Griffin, at the 56th International Astronautical Congress in Fukuoka, Japan this past October. “If you have to ask what jazz is, you will never know”. (NASA Press Release, 2005)

After reflecting on this remark by Louis Armstrong, we have concluded there is a lot of truth in it relative to engineering excellence. However, when one tries to quantify the meaning of engineering excellence and produce some measure that those who are devoted to having metrics to use in establishing whether a particular objective or goal has been achieved, then we have some interesting observations. Does the number of patents received, professional journal publications, Ph.D.’s on staff, engineering versus non-engineers at work, positive versus negative feedbacks on products, flight vehicle successes versus failures, or profit a company makes, for example, provide a measure of engineering excellence an organization has achieved?

In the aerospace engineering arena, one can certainly equate engineering excellence to mission success, at least in the eyes of the public and, for the government, the eyes of the congress. In the final analysis, engineering excellence is one of, if not the most important goals of any engineering organization. How one achieves and maintains it is another question for which there is no simple answer. Unquestionably, an organization with recognized technical leadership that has vision, superior technical competence, and the desire to excel will achieve engineering excellence. This leadership is key for the organization's success and ability of the managers assigned to carry out the organization’s mission.

Engineering excellence is also related to the strategic management of an organization’s human capital. A recent publication (NASA Directive, 2005) issued by the Administrator of NASA stressed the point that the excellence of its workforce is the Agency’s most critical asset in accomplishing its mission safety. Ensuring that the Agency continues to have the scientific and technical expertise necessary to preserve the Nation’s role as a leader in aeronautics, earth and space science, and technology is thus significant to achieving engineering excellence.

II. TECHNICAL AUTHORITY

In August 2003 the Space Shuttle Columbia’s Accident Investigation Board issued a report documenting its investigation of the February 1, 2003, loss of the Space Shuttle Orbiter during re-entry (CAIB, 2003). The report covered an extensive review of the investigation plus the associated finding and recommendations of the Board. One of the key recommendations concerned technical standards. This recommendation is identified as R7.5-1 in the report and reads a follows:

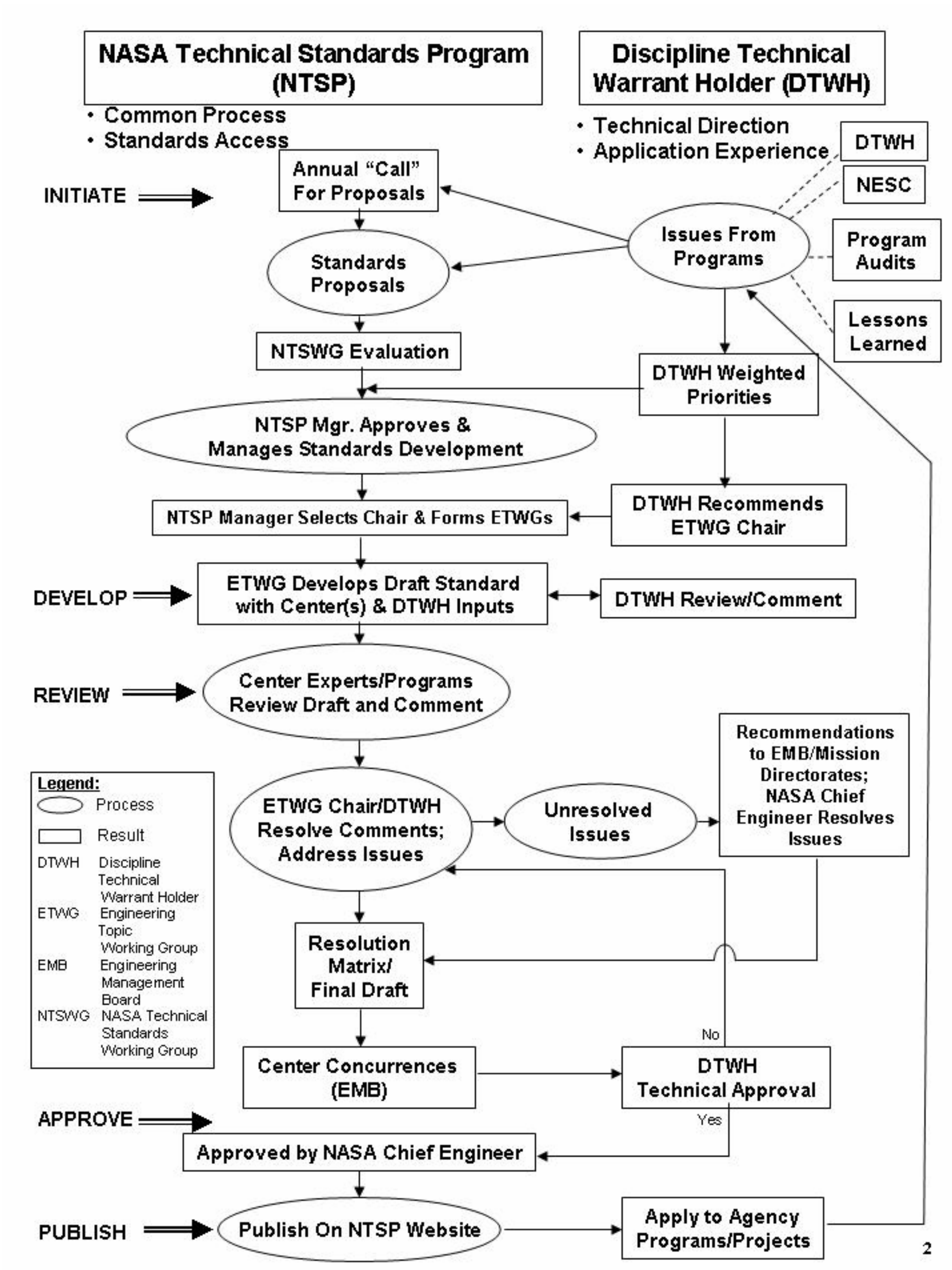
> "Establish an independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, and will build a disciplined, systematic approach to identifying, analyzing, and controlling hazards throughout the life cycle of the Shuttle System. The independent Technical Authority does the following as a minimum:
>
> 1 Develop and maintain technical standards for all Space Shuttle Program projects and elements
> 2 Be the sole waiver-granting authority for all technical standards
> 3 Conduct trend and risk analysis at the sub-system, system, and enterprise levels
> 4 Own the failure mode, effects analysis and hazard reporting systems
> 5 Conduct integrated hazard analysis
> 6 Decide what is and is not an anomalous event
> 7 Independently verify launch readiness
> 8 Approve the provisions of the recertification program called for in Recommendation R9.1-1

The Technical Engineering Authority should be funded directly from NASA Headquarters, and should have no connection to or responsibility for schedule or program cost."

Subsequent to the publication of the CAIB report, the NASA Administrator endorsed the CAIB recommendations relative to application, to the degree practical, to all NASA programs and projects, not just the Space Shuttle. Two of the technical authority responsibilities in the recommendation R7.5-1 specifically address technical standards: (1) Develop and maintain technical standards for all Space Shuttle Program projects and elements and (2) Be the sole waiver granting authority for all technical standards. In October 2003 NASA issued its report outlining the Agency's implementation plan for the Space Shuttle Return to Flight and Beyond in which it endorsed and committed to the implementation of the Board's recommendations, including R7.5-1 (NASA Plan, 2003).

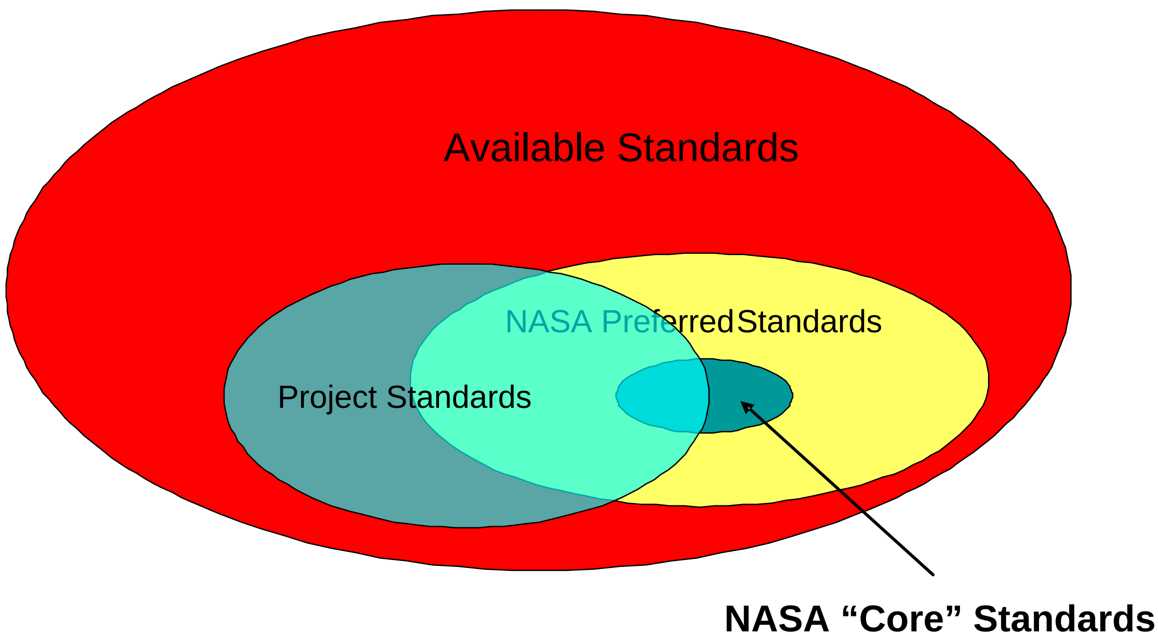
Following these actions, the NASA Chief Engineer proceeded to implement for the Agency an independent Technical Authority to set and approve technical requirements (including standards) for all NASA flight programs and projects. The focus was to ensure safe and reliable operations. Technical Authority, with the responsibility to execute, was delegated by the NASA Chief Engineer to specific individuals as System and Discipline Technical Warrant Holders. Technical standards development, maintenance, and waiver granting responsibility was part of the Discipline Technical Warrant Holders authority. Thus the implementation of the CAIB's recommendation R7.5-1 was undertaken.

With the implementation of an independent Technical Authority by NASA, and the appointment of System and Discipline Technical Warrant Holders, added emphasis was placed on technical standards development, maintenance, and waivers for use by programs and projects. This resulted in an effort to integrate the NASA Technical Standards Program into the independent Technical Authority process as outlined in the following diagram.



During the period when the Agency was focused on the Space Shuttle Return to Flight activities, and based on experiences with implementation of the independent Technical Authority, additional emphasis was placed on the need to establish a set of NASA Core Standards. These standards would be mandatory for all programs and projects to implement where applicable as part of the design and development requirements or otherwise be required to obtain waivers or tailoring approval relative to their use.

The NASA Chief Engineer implemented an action to identify a list of core standards for use by NASA programs and projects. The on going process relative to engineering excellence also led to the further emphasis on engineering authority at the NASA Centers established through policies originating from the NASA Chief Engineer and executed at the NASA Centers. Engineering authority will be focused in the respective Center line engineering elements and thereby be directly accessible to support the assigned programs and projects. They would be recognized in this respect and responsible and accountable for decisions with regard to the establishment and verification of engineering requirements on programs and projects, all variances to those requirement, and readiness for flight certification. Project level engineering requirements are to be founded upon a set of NASA Core Standards approved by the Agency under the authority of the NASA Chief Engineer.



III. ROLE OF TECHNICAL STANDARDS

Perhaps we should again consult "Mr. Webster" for what we mean by "standards". The term finds its use in a variety of ways, including meaning a "banner", "requirement of moral conduct", for example, plus "A degree or level of requirement, *excellence*, or attainment". It is with this last meaning that we associate technical standards and their role in engineering excellence.

Technical standards are an integral part of all engineering development efforts, especially those in the aerospace industry. Designers and engineers should be among the most aggressive supporters of strong technical standards. Standardization activities establish engineering and technical applications for processes and practices and, in doing so, enhance engineering capabilities and promote engineering excellence. Thus, they enable designers to not dissipate their energies on the costly exercise of “reinventing the wheel.”

The motivation for the development of technical standards varies considerably. (anon., 2005) One most often sees economic issues as the principal motivation. Applications to regulatory matters are another strong motivation. International competitiveness, commodity confidence, safeguards for health, safety, and environment, reducing risks, facilitate commercial communications, and technology transfer are among the principal motivations noted for technical standards (anon., 2001; Tanski, 2001). However, enhancing engineering capabilities and engineering excellence are not often seen in the list of motivations for the development and promotion of technical standards.

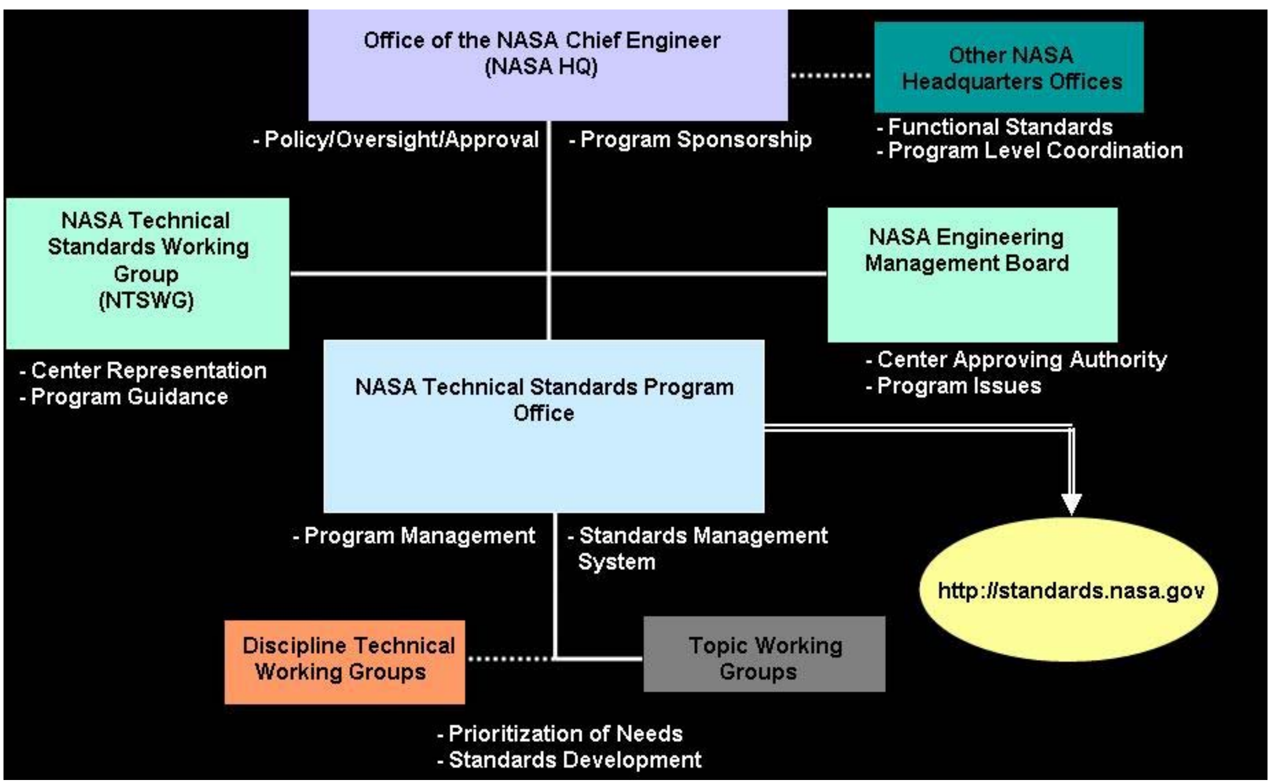
Enhancing engineering capabilities is the key to the nation’s future in the rapidly growing globalization of industry. For the United States to remain competitive and maintain its technical leadership in the world, enhancing the nation’s engineering capabilities is critical to success. These capabilities can only be achieved as a result of having achieved engineering excellence. This is necessary for the education of future engineers and the improvement of current engineers (Kelly, 2001). Technical standards provide a major opportunity to achieve the goal of enhancing engineering capabilities and providing a means whereby engineering excellence can be infused into the process. This has been one of the motivating purposes of the NASA Technical Standards Program.

Enhancing engineering capabilities and excellence is an important value of technical standards, especially when coupled with allied information such as engineering lessons learned and experiences with use of the standard. (Gill, Vaughan, and Garcia, 2001) Such is a thrust of the NASA Technical Standards Program. This thrust is being reinforced and expanded based on feedbacks from the engineering staff of NASA and its supporting contractors. This integration is one step toward the goal of significantly enhancing the engineering capabilities and engineering excellence of NASA and the aerospace industry to meet the future demands for timely, productive, and reliable space systems, plus contributing to improved costs. (Gill and Vaughan, 2003)

IV. NASA TECHNICAL STANDARDS PROGRAM

NASA has had an Agency-wide Technical Standards Program for about ten years to serve the Agency’s needs for engineering standards. Prior to the formation of the program, technical standards were the purview of the various NASA Centers and the Agency’s programs and projects. There were very few Agency-wide technical standards, mainly in the area of safety. However, there were a multitude of Center and program and project developed specific standards. Some were used by more than one Center or program or project, as deemed appropriate. In addition to providing a process for the development of Agency-wide engineering standards, and the adoption (endorsement) of non-NASA standards (other government and non-government) as Agency-wide engineering standards, efforts are being made to convert existing Center/Program/Project standards as Agency-wide standards.

The NASA Technical Standards Program was formally established in 1997 by a directive from the NASA Administrator (NASA Directive, 1997/2003). The Program's objectives are to (1) develop internal standards where available standards are not adequate, (2) evaluate, support, and adopt (endorse) national and international standards when they meet NASA's needs, (3) provide access for Agency to full-text standards via a common website, (4) link standards to engineering lessons learned and application notes (experiences using the standard), and (5) provide automatic notices on updates for standards requested by users. The Program functions under the NASA Chief Engineer and is supported by a NASA Technical Standards Working Group with senior engineering representatives from each NASA Center plus several Hq. Offices. This is outlined in the following figure. The Program serves the technical standards interests and needs of NASA employees and supporting contractors. An interview with the NASA Technical Standards Program Manager published in June 2005 (Updegrove, 2005) addresses many key points concerning the Program.



A summary of the users of the Agency's On-line Technical Standards System indicates the following usage being made of technical standards: (1) development of requirements for programs/projects (24%), (2) support in-house research and development (29%), (3) verification of a contractor's processes on program/project

(17%), (4) acquisition of parts or materials (9%), (5) proposal evaluation (4%), (6) education and training (12%), and (7) other uses (5%). In the context of the importance of technical standard in engineering excellence, this demonstrates the relative roles played by technical standards.

One of the Program's objectives is to develop internal standards when the available standards produced by non-NASA organizations are not adequate to meet the Agency's needs. In addition to meeting the needs of the Agency's programs and projects, this effort contributes directly to the enhancement of engineering capabilities and excellence within the Agency. The following table provides a sample of 25 engineering standards currently being developed by the Agency under the sponsorship of the NASA Chief Engineer. They span a rather broad range of engineering disciplines.

Doc Number	Title	Start Date
NASA-STD-5009	NDE Requirements for Fracture Control Programs	1/1998
NASA-STD-6008	NASA Fastener Integrity Requirements	11/1998
NASA-HDBK-5013	Pyrovalve Application and Performance Handbook	2/2000
NASA-STD-6004	Selection of Metallic Materials for Stress Corrosion Cracking Resistance	1/2001
NASA-STD-7007	GPS Test Standard	1/2001
NASA-HDBK-6015	Radiation Effects on Non-electronic Materials Handbook	3/2001
NASA-STD-7006	Charged Particle Radiation Testing of Materials to Emulate Space Environment Exposure	2/2003
NASA-STD-5001A	Structural Design and Test Factors of Safety For Space Flight Hardware	6/2003
NASA-HDBK-4002A	Avoiding Problems Caused by Spacecraft On-orbit Internal Charging Effects	10/2003
NASA-STD-4005	LEO Spacecraft Charging Design Standard	10/2003
NASA-HDBK-5014	Nondestructive Evaluation (NDE) Implementation Handbook for Fracture Control Programs	10/2003
NASA-STD-6001A	Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials In Environments that Support Combustion	10/2003
NASA-SPEC-6012	Protective Finishes for Space Vehicle Structures	10/2003
NASA-HDBK-7008	Spacecraft Structural Dynamics Testing	10/2003
NASA-STD-6014	Evaluation of Load Carrying Capability of Lap Braze Joints Containg Flaws	5/2004
NASA-STD-3000C	Manned-Systems Integration Standard	6/2004
NASA-STD-7001A	Payload Vibroacoustic Test Criteria	7/2004
NASA–HDBK-1001A	Terrestrial Environment Criteria Handbook for Use in Aerospace Vehicle Development	10/2004
NASA-STD-5018	Structural Design and Verification Requirements for Glass, Ceramics and Windows in Human Space Flight Applications	1/2005
NASA-STD-6016	Standard Manned Spacecraft Requirements for Materials and Processes	1/2005
NASA-STD-6019	Standard for Evaluating the Contamination Transfer Potential from Process Support Materials	1/2005
NASA-HDBK-5015	Nondestructive Evaluation (NDE) for Aerospace Composites (LaRC)	3/2005
NASA-STD-6017	FOD Prevention Standard	3/2005
NASA-STD-6018	Guidelines for Utilization of Composite Materials in Oxygen Storage Tanks	3/2005
MSFC-HDBK-6020	Compilation and Evaluation of Existing Data on the Compatibility of Materials with High-Test Hydrogen Peroxide	3/2005

These NASA developed standards are in addition to other standards under development. Currently about 150 NASA employees are participating in the preparation of standards by non-government standards developing organizations, both national and international.

V. CONCLUDING REMARKS

This paper has endeavored to focus on the subject of engineering excellence and the role technical standards plays in this important subject. Not only is the quest for engineering excellence a significant matter for the aerospace industry, both for government and non-government organizations, but it is equally important for the non-aerospace industry. Technical standards are an important element of engineering excellence. The role standards play includes the transfer of engineering experience, lesson learned, best practices, and infusion of new technology for the further enhancement of engineering excellence within all organizations. Thus, not only do technical standards support the achievement of engineering excellence, they enable engineering excellence to be passed on to others. While engineering excellence is not easy to quantify, there is no doubt it is readily recognized, both by those involved in engineering activities as well as those who are the "customers", be they public, congressional, or otherwise. In this regard the NASA Technical Standards Program is endeavoring to ensure that technical standards play a viable role as part of NASA's engineering excellence plus the aerospace industry in general.

NASA TECHNCAL STANDARDS PROGRAM WEBSITE

http://standards.nasa.gov

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