How Can Engineers Help Save Historic Bridges[1]

BACKGROUND

America's historic bridges date as far back as the 17th century (Fig.1. Pennypack Creek Bridge (1697), spanning Pennypack Creek at Frankford Avenue (U.S. Route 13), Philadelphia, PA) and, extend up to modern suspensions (Fig.2. Bluff Dale Suspension Bridge, spanning Paluxy River at County Route 149, Bluff Dale, TX), concrete (Fig.3. Lake City Bridge, spanning North Raccoon River, Lake City vicinity, IA), and moveable spans (Fig.4. Chicago Bascules, 1920s and 30s). Historic bridges are the single most visible icon of the civil engineer's art. Bridge building evolved over the last two hundred years in America, driving some of the most important developments in structural design and material technology. Examples from all periods remain, but many have an uncertain future.

About twenty years ago, under direction from the Federal Highway Administration, most states began inventorying and identifying their historic bridges to determine which ones were eligible for listing on the National Register of Historic Places. This major first step is nearing completion. Historic bridges are one of the first structure types to be comprehensively inventoried on a national scale. Significant progress also has been made by increasing the awareness of highway officials and engineers, Congress and the public to

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Until his retirement in October 2003, Eric worked with the Historic American Engineering Record (HAER), a federal program established in1969 to create a national archive of America's engineering, industrial and technological heritage. His tenure at HAER extended for 32-years, half that time as senior program manager. He administered the program in such a manner that the act of documentation not only created a permanent record of drawings, photographs and histories for the national collection at the Library of Congress, but promoted the physical preservation of that technological heritage. As Chief, he served as the Departmental and Park Service authority on engineering and industrial heritage, representing the United States at national and international conferences and symposia. Eric inspired a new generation of engineers in working with the nation's transportation and engineering resources. He sought to involve engineers in the protection, preservation and stewardship of the historic built environment. He helped established a national ethic and awareness of America's technological heritage promoting the redevelopment potential of historic industrial buildings, engineering and technological resources. In recognition of his work, he has received numerous awards including a career achievement citation from the American Society of Civil Engineers (ASCE) and, the General Tools Award for sustained, distinguished service to the cause of industrial archeology by the Society for Industrial Archeology (SIA). In retirement, he hopes to continue working with engineers, transportation authorities, individuals and communities to save the historic bridges of the United States. He is considered one of the world's leading authorities on the history of bridges.

the value that bridges hold for the historic built environment and life qualities in our communities.

One only has to look at the number of historic bridges that have been saved to realize the potential that bridges hold for creating a unique sense of place, identity and amenity, for both urban and rural landscapes. Rehabilitating historic bridges not only saves significant historic resources, but can be economically rewarding and a sound engineering practice. Some of the most innovative, cost effective engineering practices are represented by rehabilitated historic bridges. Despite these successes, recent statistics suggest that our historic bridges remain a heritage at risk. (Fig. 5. Bow (Old Corinth Road) Bridge(1885), spanning Sacandaga River at Corinth Road, Hadley, NY)

Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA)
Since 1991, federal legislation has inspired an important transformation within the transportation community, broadening its mission from the traditional task of providing a safe and efficient highway system to acknowledging that these activities play a critical role in preserving our nation's natural and historical heritage. Despite this cultural shift recent statistics suggest that half, if not more, of our Nation's historic bridges have been lost in the last twenty years - two decades in which transportation and preservation consciousness was at a high level. This is an alarming and sobering statistic. While we are not quite at the threshold of saving "the few surviving examples," we are fast approaching that point. Clearly, the Historic Bridge Program (Section 144(o)) enacted in 1987 (Surface Transportation and Uniform Relocation Assistance Act (STURAA)) is not working to stem the loss of historic bridges. Hence, the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), the SRI Foundation, the National Trust for Historic Preservation (NTHP), and the Historic American Engineering Record (HAER), National Park Service (NPS), organized an invitation-only workshop of experts to articulate and define the issues confronting historic bridges.

The workshop was held in Washington, DC on December 3-4, 2003. In the spirit of stewardship, streamlining, and sound environmental and historic bridge management, the goal of the workshop was to provide federal and state transportation agencies, the Congress, and the interested public with recommendations and solutions on how to preserve this heritage at risk. Specifically, the purpose of the workshop was to articulate and define efficient and economical strategies for historic bridge preservation and management. (Fig.6. Upper Bridge at Slate Run (1890), spanning Pine Creek at State Route 414, Slate Run vicinity, PA)

(Fig. 7. "Eureka!" Structural analysis of the Slate Run Bridge, a classic wrought-iron Town lattice truss, by Steve Buonopane, gives a clear picture of how truss members behave under

load. Graphics like this enable ordinary citizens to comprehend structural phenomenon thus easing the mystique of structural engineering bringing structures to life.)

(Fig. 7a. Upper Bridge at Slate Run showing diagonal axial forces under dead load and roadway live load, Steve Buonopane, PE.)

(Fig.7b. Stress Analysis of Upper Bridge at Slate Run showing chord axial forces under dead load and roadway live load, Steve Buonopane, PE.)

Historic Bridges: A Heritage at Risk Workshop[2]

The Historic Bridge Workshop, held at AASHTO headquarters in Washington, DC, December 3-4,2003, was one of the first professional forums where *ASCE Policy Statement 504,* adopted by ASCE's Board of Direction November 11, 2003, was presented.[3]

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[2]See http://www.srifoundation.org/pdf/bridge_report.pdf for the report on the recommendations of the Historic Bridge Workshop.

[3]***Policy:*** *The American Society of Civil Engineers (ASCE) supports the maintenance, repair and rehabilitation of historic bridges preferably in continued vehicular use, and when that is not possible, some alternative transportation means such as a pedestrian or bike bridge.*

Issue: *Bridges are a visible icon of the civil engineer's art. Historic bridges are important links to our past, serve as safe and vital transportation routes in the present, and can represent significant resources for the future. Rehabilitation maintains these important engineering resources in service and can represent significant cost savings. By demonstrating interest in the rehabilitation and reuse of historic bridges, the civil engineering profession acknowledges concern with these resources and an awareness of the historic built environment.*

Rationale: *Many historic bridges can still serve the nation's transportation needs, given appropriate repair, maintenance and flexibility in interpreting transportation standards as suggested by national transportation policy. Due to perceived functional obsolescence, lack of cyclical maintenance, and any funding priority, historic bridges are a heritage at risk. Over half the historic bridges of the United States have been destroyed during the last twenty years.*

Vehicular use is the best preservation because it keeps the bridge in traffic maintenance, inspection and funding programs. When not possible to continue in vehicular use on primary routes, consideration must be given to relocating historic bridges to routes receiving lighter volumes of traffic or alternative means of transportation such as hiking trails and bikeways. America is developing a comprehensive network of scenic highways and byways. Tandem to this is a network of hiking trails and bikeways. Maintaining and relocating historic bridges to these

I included this policy because it reinforces, from an engineering point of view, the imperative that engineers must become involved with the preservation of the Nation's historic bridges if there is any hope of saving representative examples. The fact that engineering students get little course work on engineering heritage, the history of the profession much less how to rehabilitate historic bridges was pointed out by several of the engineering educators attending the workshop.

(Fig. 8. Smithfield Street Bridge (1883), spanning Monongahela River on Smithfield Street, Pittsburgh, PA. The author and graphic designer, Michael Beard, who created a poster of Pittsburgh's bridges, are planning a book, "City Bridge," that will feature Steel City and other cities that have outstanding families of bridges: Boston, New York, Philadelphia, Washington, Cleveland, Chicago, Portland, Los Angeles).

One of the engineering educators participating in the work shop was Professor of Civil Engineering Dario Gasparini, PE (Case Western Reserve University, Cleveland, OH). Preserving historic bridges requires the technical expertise of engineers. However, engineers and engineering educators interested in our engineering past are rare. There are many reasons for this but the one most critics point to is the fact that little in engineering education prepares students to deal with issues such as aesthetics, much less concepts of cultural landscapes, preservation, or for that matter, restoring historic bridges. Some engineering educators maintain that course requirements are already overloaded just to get across the basics of sound engineering. Anything having to do with aesthetics and related

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systems sustains the scale, character and feeling of these historic, recreational and scenic corridors.

There is growing public interest in historic bridges. Citizens groups throughout the country are working to save historic bridges. We, as civil engineers, need to help lead and support these efforts. Bridges are engineered resources thus requiring the skills of engineers. There is little chance that the historic bridges of the United States can be saved without the interest and skills of engineers. Until they become part of everyday transportation policy, receiving the support of transportation officials at all levels, including the continued interests of citizen groups, historic bridges are doomed.

(This policy statement was submitted by Jerry R. Rogers, PhD, PE, F.ASCE and John F. Graham, Jr., PE, F.ASCE. Approved by the History & Heritage Committee July 12, 2003; approved by the National Transportation Policy Committee September 15, 2003; approved by the Board Policy Committee September 17, 2003; adopted by the Board of Direction November 11, 2003).

issues must be found outside the engineering curriculum and, most likely, on the student's own time.[4]

HAER and Engineering Heritage Education

In its early years during the 1970s, HAER (Historic American Engineering Record) tried hiring engineering students on its summer teams, but found that engineers had limited skills in producing drawings, photographs, or histories - the main products of HAER documentation projects.[5] While most engineering students understood structural behavior and were familiar with the latest computer programs to analyze modern bridges, rarely did they have the background or experience to analyze historic bridges. Pinned connections, built-up sections, and archaic materials such as cast and wrought iron are not taught in building material and structural engineering classes. As Professor Gasparini explained: "Most practicing engineers would be hard pressed to answer exactly how old bridges behave much less where to get information on such archaic materials as cast and wrought iron, early steels and reinforced concrete."

(Fig.9. Bridge 28: Gothic Arch (1864), spanning bridle path south of tennis courts at northwest edge of Reservoir, Central Park, New York City, NY, one of five cast and wrought iron bridges designed by Calvert Vaux and Jacob Wrey Mould to separate equestrian from pedestrian traffic in Central Park. Jet Lowe, HAER Photographer, HAER Collection, Library of Congress.)

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[4]Eugene M. Farrelly and Dawn M. Harrison, civil engineering students, Case Western Reserve University, under the direction of Professor of Civil Engineering Dario Gasparini, completed reports on the structural characteristics of iron bowstring and concrete arch bridges documented in Iowa. These HAER reports can be accessed online through the Library of Congress's Web page, "*Built in America*," http://memory.loc.gov/ammem/collections/habs_haer/

[5]HAER, a program of the National Park Service established in 1969 by the Congress, documents the nation's engineering and industrial achievements of historic significance. Documentation, in the form of large-format photographs, histories, engineering analyses, measured and interpretive drawings, is compiled primarily by students of architecture, landscape architecture, engineering, and history during the summer months. Records are deposited in the Prints and Photographs Division of the Library of Congress, where they form one of the first collections to be scanned and placed online as part of the National Digital Library, Library of Congress. The architecture, engineering, and design collection is in the public domain, available to the public without restriction (other than the courtesy of a credit line identifying the author, delineator, or photographer. All the illustrations in this paper were downloaded from the HAER Collection, Library of Congress), http://memory.loc.gov/ammem/collections/habs_haer/

Beginning about ten years ago (1996), under the leadership of Gasparini and HAER Chief Eric DeLony, HAER began hiring engineering students again to work on its summer surveys along with the architects, landscape architects and historians, but this time under the guidance of Professor Gasparini. Thus evolved one of the most innovative aspects of the HAER documentation program: to evaluate not only the structural capabilities of historic bridges, but to analyze their performance and behavior enabling assessments of the efficiency of the design, how engineers conceptualized their bridges reconciling structural theory with the practicality of constructing a buildable product in often remote locations. We now are able to compare similar designs types such as iron bowstrings and concrete arches and say something definitive about their efficiency, performance and behavior.

Other engineers and engineering educators soon joined with Gasparini and DeLony to engage engineering students in HAER documentation: Stephen Buonopane (Bucknell University), Ben Schafer (Johns Hopkins University), Tom Boothby (Penn State), Justin Spivey (Robert Silman Assoc., PC, New York), Dan Schodek (Harvard) and John Ochsendorf (MIT). Under the leadership of HAER staff engineer Larry Lee, the program continues. At the end of this paper is a listing of journal articles, HAER reports, and conference presentations made by these engineers and their students.

(Fig. 10. Exterior, Hyde Hall Covered Bridge (1830), the oldest covered bridge in the US, East Lake Road vicinity, East Springfield, NY.)

National Historic Covered Bridge Preservation Program (NHCBP)
National Historic Covered Bridge Program was funded under Section 1224(b) of the Transportation Equity Act for the 21st Century. Since 2000, under the leadership of Federal Highway Administration engineer Steve Ernst, nearly $26 million has been allocated helping 149 covered bridges. $2.3 million (9%) has been dedicated to education and research like HAER's national covered bridge documentation program. There was no NHCBP funding in 2004 and 2005. This year, 2006, the program was authorized at $40 million, and appropriated at $8.3 million. The program is administered through state departments of transportation. Requests for proposals for rehabilitation projects will be made by FHWA late this summer or autumn, and awards announced by the new year. http://www.fhwa.dot.gov/bridge/covered.htm

I was invited to serve on FHWA's NHCBP awards panel in 2001. We allocated $7 million dollars over seven hours, one of the most gratifying days of my federal career. I remember that at the end of the day, Steve Ernst said there was about $900,000 still on the table – did anyone have any ideas on how to spend it? I raised my hand suggesting that this would be an ideal time to document a selection of America's covered bridges. The next morning, Steve called asking that I flesh out the idea in more detail. HAER's senior historian, Rich O'Connor, and I came up with a five-part program: documentation, national historic

landmark designation, an exhibit, a national covered bridge web site, and a national conference.

As part of the NHCBP program, the Federal Highway Administration (FHWA), in partnership with the National Park Service, Historic American Engineering Record (HAER), proceeded with a project to document a selection of the covered bridges in the United States. The HAER project provided a rich learning laboratory for engineering students. Conducted over a three year period (2001-2003), HAER documented 75 of the nation's estimated 800 covered bridges. A significant component of the project was structural evaluation of selected covered bridges. HAER worked with engineering educators such as Dr. Gasparini and students to analyze a selection of these bridges. The results of these investigations are referenced below.

HAER documentation - drawings, photographs and histories - is designed to paint a fairly complete picture of America's engineering and industrial heritage. Over 1,000 bridges have been recorded.

Three of the five objectives have been accomplished. Yet to be done is nomination of a selection of the nation's outstanding covered bridges as National Historic Landmarks. This is the nation's highest form of recognition signifying the bridges value as national treasures, providing a modicum of protection. A national covered bridge data base including a photo, date of construction, builder and location would be extremely helpful to scholars and the traveling public.

If there is anything new and innovative about the HAER documentation package, it's the engineering analyses. To me, this is the first time that information and insights on the structural capacities of these types of bridges are being revealed. For example, Professor Gasparini discovered that Stephen Harriman Long, as far back as 1830, had developed prestressing techniques using wedges on the diagonals of the Long truss. Between the arch and the frame of a Burr arch, we were able to determine that the arch carried primarily live loads while the frame carried the dead load and stiffened the structure. Read the reports to learn about these remarkable discoveries.

Best Practices, Care and Repair of Covered Bridges National Conference, University of Vermont, June 5-7, 2003

In addition to the summer recording projects was the first *Best Practices, Care and Repair of Covered Bridges National Conference*. This was targeted to attract state and local highway engineers, state and county covered bridge maintenance personnel, volunteers charged with raising funds for the preservation of covered bridges, local and national covered bridge preservation organizations, historic preservationists, general contractors, structural engineers, covered bridge historians, the traveling public and community members. http://www.uvm.edu/coveredbridges/conference/2003.html

The conference was held at the University of Vermont, June 5-7, 2003, in Burlington. Noted author and engineer, Henry Petroski, Duke University, was the plenary speaker at the opening session. US Senator James Jeffords (I-VT), father of the national covered bridge program, offered closing remarks.

The National Historic Covered Bridge Best Practices Conference was the first of its kind to collect and benchmark the vast array of information that exists on covered bridges by inviting all those concerned with covered bridge preservation to participate. A goal of the conference was to develop a national reference base for evaluating various treatments of historic covered bridges in ways that will maintain their historic integrity as National Register properties. The conference also intended to promote a dialogue of the diverse ideas, experience, techniques and practices for historic covered bridge preservation.

The conference was presented as part of The Preservation Education Institute in partnership with the National Park Service (HAER in Washington, DC and the Historic Preservation Training Center in Frederick, Maryland) and the University of Vermont Historic Preservation Program.

At the end of these remarkable three-days, participants developed and approved the *Burlington Charter for the Preservation of Historic Covered Bridges*. This document will serve as a model for treatment of covered bridges in Vermont and may prove to be a model in other states and the country. http://www.uvm.edu/coveredbridges/charter.html.

SITES Traveling Exhibit: *Spanning Engineering and Culture: America's Historic Covered Bridges*

Another benefit of the NHCBP is a traveling exhibit that displays and interprets HAER documentation for the larger public. Under HAER staff historian Lola Bennett and HAER architect Christopher Marston's fertile imaginations, the exhibit showcases photographs and detailed architectural and engineering drawings from HAER's covered bridge program along with bridge-related artifacts from the Smithsonian Institution's vast collections. *Spanning Engineering and Culture: America's Historic Covered Bridges* explores the many ways covered bridges criss-cross the American countryside and affect its daily life. HAER's staff photographer, Jet Lowe, captured intriguing images of structural details and produced stunning black-and-white and color portraits of bridges and their surrounding landscapes. The drawings include intricate renderings of structural elements and exploded diagrams illustrate and explain how the bridges are constructed. The artistic quality of the photographs and the astonishing detail of the drawings draw attention to the beauty and integrity of each span. http://www.sites.si.edu/exhibitions/exhibits/bridges/main.htm

The exhibit opened March 4, 2006, at The State Museum of Pennsylvania, Harrisburg, and will travel to the Montshire Museum of Science, Norwich, VT (8/5/06-10/15/06), the

Chico Museum, Chico, CA (1/27/07-3/25/07), and the Bennington Museum, Bennington, VT (4/14/07-6/10/07). Contact Shannon Perry, SITES, (202)633-3138, for scheduling; Katherine Krile, (202)633-3108 for content.

Bridge Cities

The last project I want to mention is a works-in-progress. The author and Portland (OR) graphic designer, Michael Beard, Errol Graphics (http://errolgraphics.com/), who created a poster of Pittsburgh's famous bridges, want to publish a book entitled ***Bridge Cities***. It would feature the bridges in some of America's most notable bridge towns: Boston, New York, Philadelphia, Washington, Pittsburgh, Chicago, Portland and Los Angeles. We seek support and further suggestions as we launch this project.

Recent scholarship and best practices on historic bridges, TICCIH-Terni, Italy, September 14-18, 2006

Finally, TICCIH (The International Committee for the Conservation of Industrial heritage) is discussing formation of an historic bridge/infrastructure/public works special interest group. TICCIH is a global organization which has been in existence for 30 years promoting the preservation, conservation, investigation, documentation, research and interpretation of engineering and industrial heritage. To this end TICCIH will sponsor an historic bridge session at the TICCIH congress held in Terni, Italy, September 10- 25, 2006. Here, not only will there be presentations on current historic bridge scholarship and best practices, but the formation of a special historic bridge/infrastructure/public works special interest group. Anyone wishing to share their ideas and support such a group can contact the author via TICCIH headquarters, ticcih@gencat.net

Conclusion

Replacement and rehabilitation of old bridges has stimulated interest in their preservation and history in the United States and other parts of the world. In the US, recent statistics suggest that half, if not more, of America's historic bridges have been lost in the last twenty years - two decades during which transportation and preservation consciousness was at the highest level. Engineering and transportation always has had significant impacts on the historic built environment. For over a quarter of a century, consulting engineers, highway officials and federal transportation authorities, industrial archeologists, preservationists, citizen groups and individuals have been grappling over the decision to rehabilitate or replace historic bridges. Certainly, these is no argument that a selection of our most outstanding spans and representative examples of our more common historic bridge types shouldn't be saved for posterity.

I hope those of you in the engineering, transportation and bridge construction industry will find this summary of activities in the historic bridge community of interest. We call ourselves "pontists" and invite you to join our cause - preservation of a selection of the

historic bridges of the United States. Come forward if you want to participate in this gratifying yet challenging venture.

Journal Papers

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Stephen Buonopane, Justin Spivey, Dario Gasparini. "Engineering Analysis as a Historical Documentation Tool: Recent Work of the Historic American Engineering Record," *Proceedings of the First International Congress on Construction History, Vol. I, Madrid, January 20-24, 2003*, Instituto Juan de Herrera, Escuela Tenica Superior de Arqitectura de Madrid, Santiago Huerta, editor, 2003.

Stephen Buonopane, Mark Brown. "History and Engineering Analysis of the 1890 Cable-Stayed Bluff Dale Bridge," *Proceedings of the First International Congress on Construction History, Vol. I, Madrid, January 20-24, 2003*, Instituto Juan de Herrera, Escuela Tenica Superior de Arqitectura de Madrid, Santiago Huerta, editor, 2003.

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Dario Gasparini, J. Bruckner, Francesca da Porto. "Time-dependent Behavior of Posttensioned Wood Howe Bridges," ASCE *Journal of Structural Engineering*, Vol. 132, No. 3, March 2006, p. 418-429.

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HAER Documentation:

http://memory.loc.gov/ammem/collections/habs_haer/

Stephen Buonopane, Dario Gasparini. "Structural Study of Texas Cable-Supported Bridges," HAER TX-104, HAER Collection, Library of Congress, 2000.

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Dario Gasparini, Dawn Harrison. Structural Study of Reinforced Concrete Arch Bridges, HAER IA-89, HAER Collection, Library of Congress, 1996.

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Dylan Lamar, Ben Schafer. "Pine Grove Bridge: Engineering Report," HAER PA-586, 45pp, addendum, HAER Collection, Library of Congress, 2002, (not yet digitized).

Francesca da Porto and Dario Gasparini, addendum to the "Pine Bluff Bridge" HAER IN-103, HAER Collection, Library of Congress, 2002, (not yet digitized).

Francesca da Porto and Dario Gasparini, addendum to the "Eldean Bridge" HAER OH-122, HAER Collection, Library of Congress, 2002, (not yet digitized).

Megan Reese and Dario Gasparini, addendum to the "Harshman Bridge," HAER OH-126, HAER Collection, Library of Congress, 2003, (not yet digitized).

Rachel Sangree, Ben Schafer. "Taftsville Bridge: Engineering Report." HAER VT-30, HAER Collection, Library of Congress, 15pp. addendum, 2003, (not yet digitized).

Rachel Sangree, Ben Schafer. "Contoocook Railroad Bridge: Engineering Report," HAER Collection, Library of Congress, HAER NH-38, 32pp. addendum, 2003, (not yet digitized).

Rachel Sangree, Ben Schafer. "Morgan Bridge: Engineering Report," HAER Collection, Library of Congress, HAER VT-33, 37pp, addendum, 2003, (not yet digitized).

Daniel Schodek, Justin Spivey, ed. Structural Study of Seven Massachusetts Bridges, HAER MA-127, HAER Collection, Library of Congress, not yet digitized.

Daniel Schodek. Atherton Road Bridge, HAER MA-17, HAER Collection, Library of Congress, 1990.

Daniel Schodek. Ponakin Road Bridge, Forces in Truss Members, Sheet 6/6, HAER MA-13, HAER Collection, Library of Congress, 1990.

(Fig. 11. Drawing showing forces and behavior of the Ponakin Road Bridge (1871), a Post truss spanning Nashua River on Ponakin Road, Lancaster vicinity, MA. Rudolph Sosef,

ICOMOS Architect, Netherlands, under the direction of Professor Dan Schodek, PE, delineator, HAER Collection, Library of Congress.

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