California Innovation Corridor

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Pilot Program for Professional and Graduate Student Internship to Explore Innovation and Entrepreneur Environment

WIRED California Innovation Corridor Task 1.5

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Creating Innovation: No Magic Formula

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Abstract

Innovation is a mystical process that is producing new things. What are those things? It depends upon the individual views of what is important to them at a particular time. This paper will present the results of a project to define the conditions that created technical innovation in California. This project was funded by the WIRED Project managed by the California Space Authority with funding from the US Department of Labor.

Initial Approach

This project was funded by the WIRED (Workforce Innovation in Regional Economic Development) Project managed by the California Space Authority (CSA) by a grant from a proposal to the US Department of Labor (DoL) through the State of California in late 2006.

The award was for three years starting in February 2007. A task was established to look at Innovation. The title to this task was: "Pilot programs for professorial and graduate student internship to explore innovation and entrepreneur environment and provide seminars on results".

The objective of this task was to facilitate transformation of the industrial and academic innovation enterprise by building an understanding of effective practices for how innovation is encouraged and commercialized.

Who was Involved?

CSA is a not-for-profit charted lobbying organization by the State of California with the purpose of supporting and promoting aerospace business in California. With this grant from the US DoL there were 29 tasks defined to provide workforce training and business enhancement in California. One of these tasks, 1.5 "Pilot programs … seminars on results" was awarded to the Department of Aeronautics & Astronautics at Stanford University with a budget of $450,000 for a three year effort. Professor Robert Twiggs, a Consulting Faculty member of the department, was appointed as the task director.

Evaluation of Intent

The intent of the task was to determine what conditions of intellect, stimulations, rewards, incentives, etc produced innovation in recognized companies. Such companies like Google, Apple, Cisco and others were highly praised for producing new technologies and services at an amazingly high rate and volume. Other companies like Hewlett-Packard and IBM were early leaders in innovation, but now not matching the pace with the likes of Google and Apple.

The process for determining this/these "Magic Formula(s)" was for Stanford and University of California – Riverside (UCR, a WIRED supported task member) to appoint small teams of faculty, industry professionals and students to spend a short internship (3-5 days) as observers in this highly innovative environment. This team will meet after each internship session to concisely record their observations. The group will serve from 2-4 internships over a three months period. The team will then work together to put on a seminar or seminar sessions to give to both the public and academic community within three months of the last internship. Successful completion of this task will result in greater job creation and economic opportunity as a result of increased innovative of new technological concepts.

After evaluating this approach at the beginning of the grant period, it was felt that the method of gathering information for determining this "Magic Formula" could be better achieved by a different approach. This new approach was to form teams of students, faculty and some outside experts as an Innovation Research Team. This IRT would visit company executives and do an in-depth interview to get information for the "Magic Formula" rather than the intern approach as had been previously proposed.

Innovation Research Team Approach

The Stanford and UCR formed these IRT teams. The UCR team was formed in a formal class and the interviews were part of the class project. The results of this class would be presented as the seminars. The Stanford team was composed of students, faculty and outside executives. The constituency of this team may change over the course of the grant. Each team developed a set of questions that could be used during the interviews with the innovative company executives.

The Stanford team started with visits and interviews with executives from three different types of companies. The first was a company that provided technical services for aerospace companies. The types of individuals that they hired were experts in their fields and worked in-house with the customers. They were not hired to produce innovative solutions for their customers, but to provide expert advice during design review meetings and consult with engineers on specific problems. – no innovation need here.

The second executive was from a startup company that had just been sold to a major division of Hewlett-Packard. Here, there was a need for innovation in application of signal processing. The major comments here on creating innovation was to 1) Hire employees who were well qualified in companies area of interest. 2) Being a small startup, the small number of employees could be well rewarded in company stock for their productivity. 3) Define very well the areas of needed innovation. 4) Make sure the employee understood when to stop innovating and produce a useable product.

The third executive had retired from several businesses, but had been a vice president and manager of R&D at an early video game maker. His comments followed very closely to those of the second executive. Both of these individual had experience in management practices used in both small and large companies. Their view of the "Magic Formula" was that it was illusive and that it was so dependent upon so many variables, that there was not "Magic Formula". The aggregation of these variables determined the innovation and were dependent upon company size, products produced – did the company need revolution or evolution in their product line, personality of management, types of individuals hire – managers choice of choosing people that did not threaten their jobs and at what level was innovation accepted – only form R&D or at all levels of the company.

The fourth executive was very interesting. It was Steve Wozniak, the co-founder of Apple Computer with Steve Jobs. Why was he so innovative in developing the first Apple computer? What made Apple such a leader now in many ways with disruptive technology? The answers were very interesting.

Steve's reason for his innovation developing the first Apple computer was based on being recognized as being the smartest guy in the Home Brew Computer club in Mountain View, California in the early 1960s. That was in the days when nerds were treated different than nerds of today. They were only praised when they did something "cool" that somebody could use. One of Steve's major achievements before developing the Apple computer was to build a device that could be used to make long distance telephone calls without being charged. Was this an applicable characteristic that was part of the "Magic Formula"?

What were the conditions or environment within Apple computer that made it so innovative? An ingredient in that must have been Steve Jobs. When Steve was fired by Apple, no significant products were released. When Steve was once again a major influence at Apple, new innovative products started to be produced. IPod was an example of disruptive technology – from a computer company? Why not one of the other companies that had similar products? IPhone is another disruptive technology – why not produced by someone already in the phone business?

Steve Wozniak could not define explicitly what Steve Jobs did to remake Apple and innovative company. Was it personality? Was it leadership? Was it incentives? Was it the working environment?

Others Studying Innovation

The further the IRT got into interviews and literature searches, it was found that there was a whole large world out there working to find out what was the "Magic Formula" for innovation. At Stanford University there were four or more classes on innovation. There were research groups within Stanford with major concentrations on studying innovation. There were many seminars and workshops being offered on innovation.

The question we then had to ask ourselves in doing this WIRED program task was " What can we add to this elusive search for innovation that is not already being pursed or found"?. We felt our efforts to-date had not produced a significant return for the effort invested to continue our approach with the Innovation Research Teams. We had learned a lot about companies and innovation, but nothing that revealed anything that could be called the "Magic Formula" for innovation.

Another Change in Approach

One lesson that has been learned in the aerospace business is that people networking is very important. When visiting and working with aerospace companies, you often hear the phrase, "I wished I could get some technology to do this" or "is someone working to solve this problem". When visiting the supply side or vendors supporting the aerospace industry there is always "why aren't they (the aerospace industries) interested in this?". This then leads one to consider the process of networking these two types of parties together. To do this, you need some sort of open forum where those that "need", can communicate to those that "have". This is one of the major functions of conferences, but conferences are expensive to attend, take time in traveling and generally there is not enough time to meet and discuss with everyone the mutual interests.

Since we felt we were not producing any significant value with the IRT approach for the task assigned by the WIRED program, we decided to find a way to generate a networking system that would be more productive than conferences. With the advent of lower costs and improved capability in video conferencing, it was decided to implement a program to make these networking connections by having a series of webinars.

A New Approach

A seminar/webinar was developed as a graduate level class in the Aeronautics and Astronautics department at Stanford University. This seminar/webinar called AA247 Innovations in Aerospace and Exploration of Space was started during the spring 2008 quarter at Stanford University. Here we work to connect those that "need" to those that "have".

The use of WebEx© provided the capability to have the presenters and the attendees at any location. Graduate students at Stanford attended the class in person. There was an average over two quarter class periods of 20-25 students and remote attendees of 15-35. These seminars/webinars were done each Monday at noon from Stanford University.

These seminar/webinars were held during the spring and autumn quarter of 2008. The funding for the WIRED program ended in November 2008. Due to budget constraints in the department of Aeronautics and Astronautics, the seminar/webinar was discontinued after the autumn quarter.

Seminar/Webinar Program

The presenters for the seminar/webinar over the two academic quarter periods were:

Scott Hubbard – former Director, NASA Ames Research Center – presented in class.
John Doty, PhD – President, Noqsi Aerospace, ltd – Chief Designer & Engineer for HETE-2 - presented remotely
Dr. Owen Brown – DARPA F6 Program – presented in class
Dr. Jeff Ward - Vice President, Avionics, SpaceX - presented remotely
Donald L. Thoma - Executive Vice President Corporate Development Iridium Satellite, LLC – presented in class
Burton Lee Ph.D. – Space Angels Network, LLC – presented in class
Dr. Alan Weston – Assoc. Director, NASA Ames Research Center – presented in class
Dr. Jim Wertz - Microcosm - presented remotely
Randa Milliron - CEO/Co-founder, Interorbital Systems - presented remotely
Dr. Rick Fleeter – CEO AeroAsto - presented remotely
Dr. Owen Brown - DARPA - presented remotely
Brian Horias – formerly of DARPA - presented remotely
Elon Musk – President, CEO SpaceX - presented remotely

There were approximately 150 attendees registered to attend the class remotely. The presentations we archived with a record option in WebEx and made available for viewing at:

http://www.innovatecalifornia.net/innovationase

<u>Summary of Results from some of the Seminar/Webinar Sessions Spring 2008</u>

Definitions of Innovation
"Necessity… the mother of invention" – Plato
Innovation: 1) The introduction of something new; 2) effecting a change
Innovation: 2 types

- Evolutionary/Incremental change
- Revolutionary, paradigm-changing

Technology Wish List

The table below shows a sample of some desired and emerging new technologies that will enable further progress and exploration. The starred* items were designated as having a higher probability to acquire private funding.

When reading through this table, remember that it is not complete! Also remember the quote from Henry Ford: "If I'd have asked my customers what they wanted, they would have told me 'a faster horse'.

Propulsion/Access to Space	Mars-related	Power
Nuclear Rockets Warp Drive Ballute Decelerators Solar Sail Tugs Fly-back Boosters* Space Elevators* Low-cost access to space Small Satellites Air Taxis	Automated Mars landing Mars internal combustion engines Mars propellant production Atmosphere collection systems Permafrost mining Mars surface nav / com system Mars surface cryo-coolers Mars surface food production Simple in-situ spares manufacturing	Better batteries* Ultra-large (Football field) size solar arrays*
Human Space Flight	Communication	Other Technologies
EVA suits High-closure life support* Solar flare / proton warning Self-cleaning space toilets Autonomous surgical robots*	High data rate backhaul system	Deep space autonomous navigation* Simple raw materials production Distributed and networked s/c* Innovative Environmental

Suspended animation Low-waste food and liquid Personal Space Travel and Space Tourism*		Monitoring (aerial, space, and ground based)* Sensors and avionics Space Air Traffic Management

Environments and Situations that foster innovation:

Several speakers mentioned some situations in which innovation was born. One speaker shared inspiring quotes, and another, a 'recipe for revolution'.

Innovation Stimuli	Example
Crisis	Apollo 13
Expediency	
Adaptation	
Domain Transfer	
Entertainment	
Counter-failure	
Competition	Aerial prize: first person to fly over the Atlantic Companies competing for project proposals
Schedule pressure	US and Russia's 'space race'
Inventive Ego	
Incentives	
Inter-disciplinary co-operation	-Astrobiology: Scientists looking for life in space can learn from those that study extremophiles on earth -Bio-inspired nano-technolgoy -Entrepreneurial Space Business

Jeff Ward's "Recipe for Revolution"

- A demanding vision
- An appetite for in-sourcing
- A technology-rich environment
- Appetite for risk
- Persistence
- An evolutionary approach
- Impatience
- Simplicity
- Improvisation
- Inadequate adult supervision

Advice from Owen Brown, John Doty:

- Believe in your ideas

  "The great pleasure in life is doing what people say you cannot do" – Walter Bagehot
- Do not fear failing

  "Success teaches us nothing; only failure teaches" –Admiral Hyman Rickover
- (Try to) Avoid the Bureaucracy
- Beware of Market Research: Imagine what people might want, not necessarily what they tell you they want

  "If I'd have asked my customers what they wanted, they would have told me 'a faster horse'" – Henry Ford
- Import Technologies from other areas
  - Example: Iridium next borrowed mass-production techniques from the automotive industry to manufacture their 66 satellites + spares efficiently
- Already have a working system? Think of new ways to use/improve it

Some things to watch out for (John Doty)

- Parametric cost estimation for new technologies Produce overly large, project-stopping numbers.
- Old technology is used instead of space-qualifying New, 'riskier' parts.
- Radiation tolerance requirements are too high.

  Alternatives:
  - Choose a low-dose orbit
  - Trade margin for tolerance
  - Design for easy recovery
- Need an improved review process
  - Experts can spot problems, but often can't relate to new approaches.
  - Review by students! Un-biased review, will spark new ideas.
  - Base project milestones on hardware demonstrations, not reviews
- Management often thinks "Innovation is too risky!"

Some innovation Examples (describe in detail)

- DARPA F6 fractionated spacecraft
- Iridium: new uses for current spacecraft, and Iridium NEXT
- Lunar Lander and cold-gas propulsion technologies (Alan Weston)
- Innovative ways to get to space
  - Secondary payloads
  - SPRITE

- Low-cost (i.e. Falcon)
- Alternative Launch (Microwave Thermal Rocket)

<u>Summary of Results from some of the Seminar/Webinar Sessions Autumn 2008</u>

Following are summaries of presentations and conclusions:

Dr. Rick Fleeter, Founder, AeroAstro, Inc, Herndon, VA

Otherwise Unremarkable Stanford Engineer Founds Successful Aerospace Company. How did that happen?

– Our reality:
  - Frustration of aerospace dominated by large institutions (supply+demand cartel)
  - Dilbertian existence
  - Disenfranchised (invisible) markets
  - Fun: distinctly absent
  - Desire to see the whole picture - technically and commercially: can space matter?
  - Government is small compared with commercial
  - Where do big program leaders come from?

– Stereotype: Write Plan -> Raise $Ms -> build product -> Sales

– Our reality:
  - Write Plan -> Raise ~nothing -> start anyway
    - Forced us to learn to sell immediately
    - Taught us how to get by with nearly nothing
    - Kept us from building what nobody wanted
    - Maintained corporate control with founder and first tier employees

– Capital limited our growth, but we were more limited by inability + inexperience + disinclination to manage

– What we did wrong:
  - Chunky Business
  - Inaccessible Goals
  - Structure for 9 ≠structure for 39
  - No Money =>
  - No marketing / PR
  - No product R&D
  - η = 100%

- No strategic plan
- τ << sales cycle

– **What we** changed
  - Product Mix (e.g. radios)
  - Charge for everything
  - UMs / PMs
  - Legalize meetings
  - Create Cash
  - Sell & grant equity
  - Measure profit by job
  - $\eta < 100\%$
  - Plan sales & process
  - Mix of time scales /colossaltron mentality
  -

– Why are we still here and growing after 20 years?
  - Solid fundamental concept- market exists (was hypothetical)- technology & management are both distinctive (and related) tech, transportation & budget: favorable ecology - growth and promise of rewards do help
  - Life Force: people want it to succeed, and care personally
  - Commitments: to learning, change and longevity

– Achieve Liquidity
  - Costs vs. Benefits
  - Autonomy becomes vestigial
  - Implicit Contract With Investment
  - Maverick ages poorly
  - Flexibility v. Identity
  - Theory of the Right Buyer
  - Choices take time and effort
  - How do you know?
  - Buyer becomes the Seller

– Strategy
- Bigger Slice
  - Govt. Space & Components
  - New Gvt. Customers
- Bigger Pie
  - Sub to Primes
- More Pies
  - SENS / NVIS
  - Keep more Crumbs

- Operations
- Negotiations & Contracts

Dr. Rick Fleeter, Founder, AeroAstro, Inc, Herndon, VA
Microsatellites: Where Space and Reality Collide

– Microsatellites: worst in all respects except:
  - Rapidly developed
  - Tailored to each application
  - Low cost
  - Inherently reliable
  - Low cost (but flaky) launch
  - Simple & accessible
  - Easy to deploy in large #s

– Transportation Outlook
  - Per Kg cost constant or gradually decreasing
  - Capability per Kg rises more rapidly due to computer advances
  - Increase multiple manifesting
  - Some new players in launch business

– Thesis of enabling innovation in space
  Putting space in the hands of the maximum number, and diversity of users, to do whatever they want to do.

Brian Horias- Former DARPA program manger
Implementing the SCIENTIFIC METHOD in Space: The Need for Secondary Payloads

– Our capability to develop new space technologies is constrained due to our limited ability to conduct space component development and qualification

  - During the early years of the US Space Program we launched numerous component development secondary payloads
  - As the space Industry has matured, we have lost much of our ability to conduct space component R&D through secondary payload launches

– Observation: Since the 1990s The International Space R&D community has conducted significantly more secondary space payload launches than the U.S.

BASIS FOR OBSERVATION:

- Comparison of US Space Test Program (STP) and Ariane ASAP (Auxiliary Structure for Secondary Payloads) launch rates over the period 1990-2000
- Comparison of US Delta II versus Ariane IV ASAP Secondary Payload launches, 1990-2000

HYPOTHESIS:

- Increased frequency of testing shortens the development iteration cycle for space components and leads to more rapid introduction of new technologies

TESTING:

- Establish more frequent secondary payload launch opportunities in the US by developing the infrastructure to utilize excess payload margin on U.S. launch vehicles
- Over a multi-year period, Evaluate the impact of these additional launch opportunities on US space innovation

- Developing the opportunities

  - Developing the space component testing infrastructure and new space components in parallel may provide a basis for testing the hypothesis:
  - Use of existing excess launch capacity is an enabler for component testing
  - These Initiatives are only part of the solution:

– Conclusions

- An approach has been presented to use the scientific method to address the topic:
- To address this topic there is a need to:
  - Identify relevant components for small space payload testing
  - Develop the infrastructure to support additional secondary launch opportunities for these component test payloads

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Randa Milliron, CEO/Co-founder, Interorbital Systems, Mojave, CA 93501

– Interorbital Systems is developing innovative launch systems for earth and inter planetary use.

– Innovation in products

- Ablatively-Cooled Liquid Rocket Engines

- Completely Pressure-Fed System
- Storable, High-Density, Hypergolic Propellants
- Steering by Differential Throttling
- Multiple Fixed Low-Thrust Rocket Engines
- Low Chamber Pressure
- Single Air Start of One Stage
- "Fire in the Hole" Upper Stage Ignition
- Modular Construction
- Floating Ocean Launch

– Innovation in methods
  - Launch Flexibility Advantage
    - Allows the customer to set the launch schedule
    - Safer for manned launches
    - Allows rocket to be positioned for any orbit
    - Doesn't set a limit on the size of a launch vehicle
    - Requires only a minimum of launch support hardware
    - The most cost-effective launch option

– Applications

  - Single payloads to polar or sun-synchronous orbit (LEO
  - Single Payloads to equatorial or Molniya orbits
  - Multiple CubeSats to the above orbits (up to 12 at a time)

Dr. Jim Wertz, President, CEO, Microcosm Inc. Hawthorne, CA

The Demise of Innovation in Aerospace and Impact of the Faltering Economy

Thesis – innovation is aerospace is not occurring in the general business. It is occurring from the newcomers with their own funding.

– Aerospace does have a large number of multi-millionaires who are willing to bring lots of money to the game and some innovation, but thus far they haven't had a big impact (but that could change)

  - Examples: Jeff Bezos (Amazon.com), Elon Musk (PayPal), Andy Beal (Beal Bank in Dallas), Robert Bigelow (Motel 6/Budget Suites), Bill Gates (Microsoft)

– The fundamental difficulty is a dramatically conservative/risk averse view that

    - Doesn't want to change anything that worked before
    - Because of the huge cost overruns, won't spend $0.10 on reducing the cost of future missions
    - Of course, both of these are part of why it costs so much in the first place

- Technology developed by Microcosm and its acceptance by the government aerospace business.
    - Technology: Microcosm developed and patented autonomous on-board orbit control in the 1990's
        - Acceptance: Orbit control is traditionally a ground function
          Doing it on board is a new way of doing business and that's "bad"

    - Technology: Scorpius® is an expendable vehicle and defies the traditional logic that the only way to really reduce cost is to create a reusable launch vehicle
        - Acceptance: The Air Force argues that there isn't a need for a small satellite launcher (the first of the Scorpius® family) because they aren't convinced that small satellites are useful

- In my view, many of today's space programs behave like a herd of brontosauruses nibbling on the water lilies at the edge of the La Brea Tar Pits

- What works in innovative development for space?
    - Prizes work well for projects that can be done by an individual or small group with little or no outside funding
    - Allows individual creativity and innovation to play a key role

- From an economic perspective, I can't find a realistic scenario in which RLVs are cheaper than ELVs (Expendable Launch Vehicles)

- What Works?
    - Trade on Requirements
        - Buying a spacecraft should be like buying a car — finding the right compromise between what we want and what we can afford
    - Use Large Margins
        - If we built that car like we build spacecraft and we want a bigger radio, we would need:
        - A larger battery for more power
        - A bigger engine to supply the power
        - A stronger dashboard to support the radio
        - A bigger radiator for more cooling, etc.
    - Do Good Up-Front Mission Engineering

        - Not knowing where you're going or how to get there is rarely a good approach to getting there quickly and efficiently
    - Talk about Cost at Every Opportunity
        - Make cost an important consideration from the start -- not a nice-to-have afterthought
        - Much easier to say "First, it has to meet the requirements, then we'll think about cost"
    - Use Constellations of SmallSats
        - SmallSats, MicroSats, and CubeSats are all dramatically cheaper than traditional FatSats
        - They can do more, with newer technology, and they are easily replaced

    - Reversing the Space Spiral to reduce both cost and schedule requires simultaneously changing both the technology and process

– Inertia and Culture are two of the strongest forces in any organization

– To be successful, we must change <u>both</u> the technology <u>and</u> the process

– What we need is to finally allow innovative solutions that can reduce cost now, in the near-term (24-26 months) and in the long-term (2-8 years)
– It is possible that, having been forced to change how we do business in space, we may, in the end, create a better, more robust, more responsive, and much lower cost space program with a larger, more diverse, more cost-conscious industrial base that can compete successfully on the world market

– Start a Revolution!

– If the best and brightest of our young engineers decide they would rather work on something more meaningful, with more near-term consequences, Aerospace will change

The Space Business needs to be fun, exciting, and challenging.
It can be -- but you need to make it happen!

Dr. Owen Brown, Program Manager Tactical Technology Office DARPA/TTO 3701 North Fairfax Drive Arlington, Va

New Connections – Fractionated Space Systems

- Demonstrate a new space system architecture which replaces traditional monolithic spacecraft with a wireless "virtual spacecraft" operating as a cluster of modules.

  - Technical Approach
    - Create a architecture of distributed modules that enable all major spacecraft hardware components to function as network-addressable and shareable devices.
    - Base architectural design and system engineering trades on balancing system lifecycle value, cost, and risk.

– Attributes
  - Flexibility

  - Robustness

  - Cost - Lifecycle Cost and Value

  - Cost, Value, and Uncertainty
    - Uncertainty: Payload Delay
    - Uncertainty: Launch Failure
    - Uncertainty: On-Orbit Failure

  - Changing Risk and Opportunity

Continuing the Seminar/Webinar Program

The seminar/webinar AA247 series was discontinued at the end of the autumn quarter 2008. A survey on the seminar/webinar was sent out to all 150 registered attendees. Of the over 100 responses only two were not interested in seeing the AA247 continue. All of the remaining registered attendees were interested in continuing to watch the seminar/webinar live or viewing the archived copies. This series may be started again in the near future.

Development of Networking Web Site

Working with the Kentucky Science and Technology Corporation in Lexington, KY exploring the interest in AA247, it was decided that with this experience, there was a need for a web site that could help network the small satellite community together.

This site called:

http://sefspaceworks.com/

is now in its second full month of operation and is a central location where those that "need" can see what those that "have" on a continuous basis. This site also will be providing educational training series for small satellite development and outreach for K-2 students.

Conclusion

Although the WIRED task assigned to Stanford University did not find the "Magic Formula" for innovation, it did create two means of promoting innovation. The AA247 seminar/webinar series that will be continued in the future will provide live networking across a broad spectrum of students, industry and government organizations.

The development of the web site SEFSpaceworks.com is a continuous vehicle to link all members of the community together. The on-hands training of the students in programs through outreach to K-12 and the university programs will educate a new workforce that is steeped not only in capability but the environment to produce innovation.

The workforce of the future will be much better equipped because of the lessons learned in the tasks executed with funds from the WIRED program managed by the California Space Authority and funding from the US Department of Labor.

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