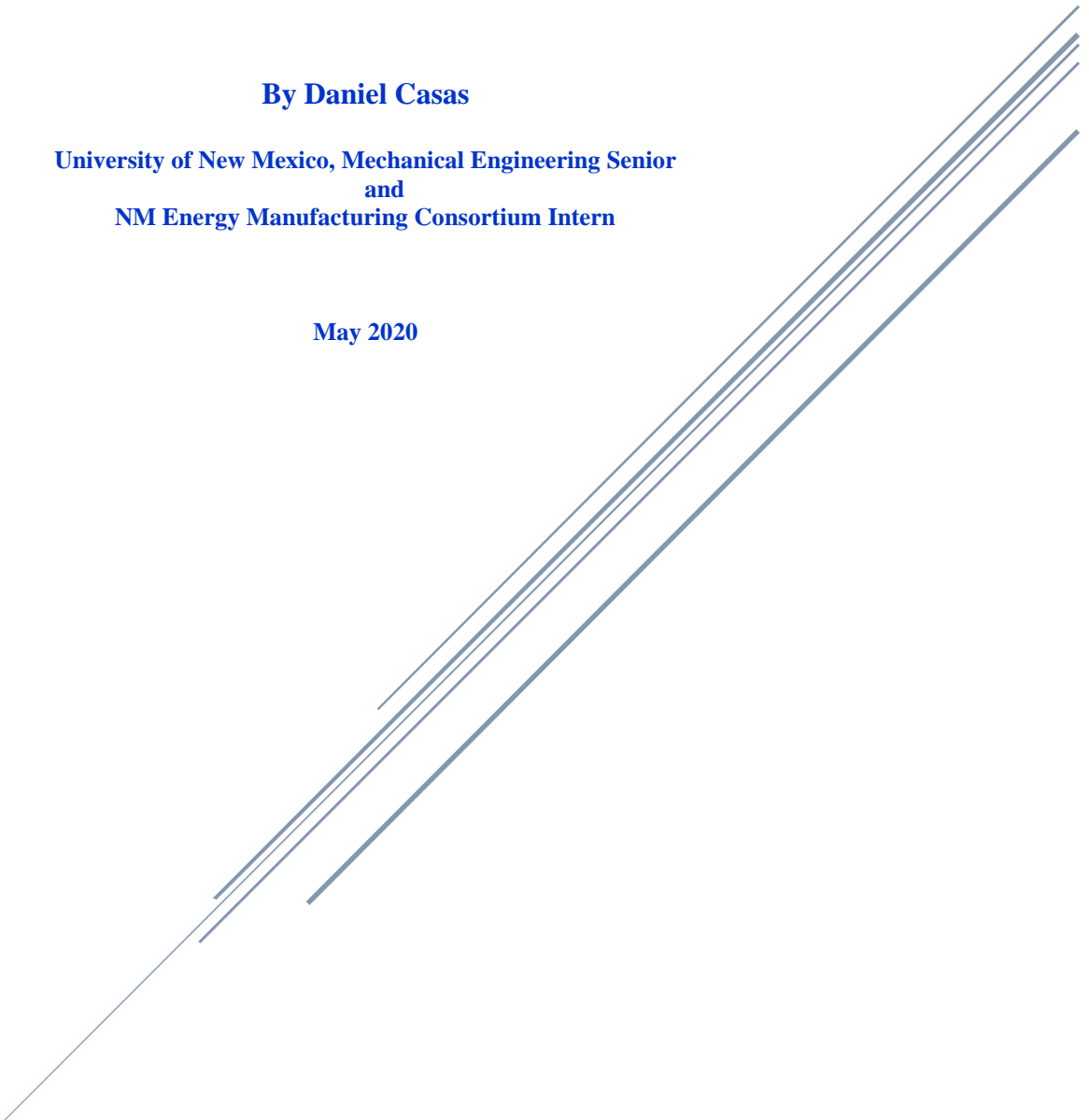


**Best in Class Collaboration**  
**in**  
**Scientific Research**

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## **Preface**

The information gathered and documented in this paper will be used to inform the detailed design of the Advanced Technology Collaborative (ATC) program which is an initiative led by the NM Energy Manufacturing Consortium. The program design will be documented in a process map, which covers initiation, management, and completion of a collaborative research engagement. The contents of this paper address collaborative research engagement where the goal is to further scientific knowledge and create innovative technology for public benefit within a short period of time.

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## Introduction

Collaboration is a critical component of scientific research, which most often is asked to address complex problems, provide new and robust technology, advance scientific knowledge, and expand highly specialized areas of expertise. One scientist can seldom provide all the expertise and resources necessary to address complex problems, and this creates a need for collaboration among members of the scientific community. Research collaboration is the foundation of the Advanced Technology Collaborative (ATC) program, led by NM Energy Manufacturing Consortium. The program is currently in its design phase, and the team determined that their implementation should follow a detailed mapping of steps to be taken. They want to use a process map to eliminate the possibility of inconsistent implementation. Although reviewed publications offer broad direction and guidance, the program development team desires an ordered process that contains the vital few, best practices.

Extensive reviews of literature and case studies were conducted, and numerous best practices were found. However, the intent of this study was to identify the vital few, necessary to map the process for a successful collaboration. The large number of best practices presented a challenge and an opportunity to mine for commonality among them to select the ones to include in the ATC process map.

To complete the process of capturing the vital few and to supplement the literature reviews and case studies, the team determined that the views of local researchers are important to the development of a process map. Therefore, a survey was created to be used in interviewing researchers in New Mexico's science and engineering community. The COVID-19 pandemic restricted in-person contact, and interviews with researchers in the state were conducted via conference calls. The survey/interview questions sought to gather information from each researcher on their previous and current collaborative experiences, work practices, and perceptions regarding collaboration in general.

This paper summarizes the contents of the literature searches, case studies, and interviews. For starters, it gives a general definition of collaboration to provide contextual meaning of scientific research collaboration as discussed in the remainder of the paper. The source of the collaborators, the mechanics of their interactions, the importance of relationships and resources, and the stages of the collaborative process are included to give context. The topic of authorship is explored very briefly to highlight career and intellectual property implications in the research process. The paper ends with interview responses given by researchers from New Mexico's research institutions. Their views confirmed most of the conclusions drawn from the literature searches and case study reviews, while providing unique insights in some areas as well.

All in all, this initial publication provides a fundamental set of best practices for research collaboration, and because it is being offered and treated as a living document, it will be refined and supplemented over time. This first installment presents key success factors that were found to be commonly observed among researchers that have participated in successful scientific collaborations.

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# Literature Search And Case Study Review

## Collaboration in Scientific Research

### **Collaboration: What, Who, How**

This paper defines collaborative, scientific research as researchers working together to achieve the common goal of discovering and producing new scientific knowledge and developing innovative technology.

**Q:** When does Collaborative scientific research make sense?

**Ans:** When it is clear that the collaboration will enhance ideas and increase creativity and when the goal of the research cannot be achieved without a collective effort.

The mechanics of research collaboration can be segmented as follows:

- **Configuration**
- **Method**

**Collaborative Configuration** refers to the source and characteristics of participants and can most often be described as follows:

- o Within research institutions (Intramural)
  - inter/intra departmental
  - graduate student members
  - etc.
- o Between research institutions (Extramural)
- o Between research institutions and government agencies
- o Between research institutions and private industry

**Collaborative Method**, on the other hand, refers to the manner in which collaborators interact with each other such as

- o Face-to-face,
- o Phone,
- o Mail (postal, electronic),
- o Social media, and
- o Video conferencing.

## Relationships and Resources

Some collaborative relationships are formed between researchers familiar with one another's work and who understand the mutual benefit of a collaboration. Others are established between researchers that have no prior working relationship but have met in settings, such as conferences, industry gatherings, or through formal introductions. The initial interactions often begin to explore the possibilities of a joint effort that could result in scientific, social, and/or economic benefit.

After the launch of the collaborative relationship, it is important to determine how interactions should take place between researchers. The mode of interactions must be carefully chosen since collaborative research projects are likely to be more complex than research conducted by individuals, and the success of the research can hinge on the success of the interactions. Well planned interactions and thoughtful attention given to the roles and responsibilities, assigned to each researcher, will help ensure the responsible conduct of scientific research and successful outcomes of the project.

To increase the likelihood of a successful collaboration, researchers should invest sufficient time during the early stages of the collaboration to form a sound relationship. The topics listed below are critical to forming and maintaining successful relationships. Neglecting any of these areas may adversely impact the progress and quality of the research and undermine the relationship:

- Determine the scope of the collaboration
- Establish and document the critical research roles and responsibilities
- Identify needed resources
- Disclose potential conflicts of interest
- Designate the terms and conditions of resource sharing
- Clarify intellectual property rights
- Determine the criteria for authorship
- Prepare a detailed Memorandum of Understanding

Collaborations cannot occur without adequate and proper resources. It is each researcher's responsibility to confirm the current or future availability of necessary resources prior to the start of a project. Necessary resources are any and all resources required for the successful completion of the research goal(s). They may include:

- Funding
- Personnel (e.g. technical and administrative)
- Data (e.g., preliminary and final)
- Equipment (e.g., specialized, diagnostic)
- Available space

Funding, which constrains the design and execution of the entire project must be secured prior to the start of project. Whereas, final decisions about personnel (skills, discipline), data, equipment, and space are usually made and published upon completion of the research design phase. Funding depends upon many



factors that are not as clearly understood as the other resources listed above, but it is prudent for a researcher to be aware of conditions that affect the probability of acquiring the necessary funding. A few of them are:

- Previous relationship with a funding source
- Choices of funding sources
- Maturity of researchers
- Past successes in acquiring funding
- Past research performance
- Funding trends

### **Stages of Collaboration**

Collaboration can be difficult, as it is comprised of many voices, individual preferences and personal, past experiences. It brings together researchers with unique strengths to work together on defined problems and to address specific research goals. A Principle Investigator (PI) leads the research effort and will address dissimilar expectations and personal ambitions to unite the team early in the process. To ensure a beneficial collaboration, the team must identify and understand each other's strengths and weaknesses and agree on a common set of values, behaviors, and norms that will define their collaboration. These principles will become increasingly important as the collaboration progresses through the necessary stages of the project toward successful completion. The stages are:

#### **• Conceptualization • Execution • Evaluation • Distribution**

**-Conceptualization** is the stage where the research methodology is planned. The research methodology or design will establish a common understanding and agreement on the 1) research thesis, 2) research goals and objectives, 3) specific project deliverables, 4) data and information to be collected, 5) means of communication, 6) criteria for authorship, 7) measurements of success, and etc. Planning the details for successful execution unifies the team around common goals and avoids potential areas of conflict that could arise from lack of preparation or collective agreement.

**-Execution** is the stage of project implementation and management. Activity during this stage will more often than not require adjustment of scope, priorities, allocated resources, schedules and processes. Organization is important for managing it all, and a key organization tool is a robust communication plan. A good plan will ensure that the amount and quality of the communication enables timely and effective responses to problems, and it also ensures that all team members receive critical information at the same time. A good plan will provide for appropriately scheduled meetings to discuss project status, identify challenges – current or pending, share data and information, and build esprit de corps.

Several formal agreements between institutions, researchers, and sponsors should have been established early in the collaboration for areas such as material/technology transfer, data ownership, authorship, copyright/patent issues. These agreements help the PI to manage compliance to policies and regulations

relative to institutional, state, national, and international requirements. Compromise or failure in compliance can have a harmful effect on the research, the collaboration and individual investigators.

In support of a well-managed execution, the value of a committed champion cannot be underestimated. If one has come forth prior to the beginning of the project, the team is ahead of the game; if not, one should be recruited as soon as possible. Occasional face-to-face meetings between the champion and the collaborators help to energize the collaborating team. In general, the PI is responsible for maintaining positive energy during the project and should maintain a focus in that regard especially if new members join the team. The PI should understand how the collaborators work - alone and together, demonstrate and appreciation for their contributions, and find ways to maintain morale.

**-Evaluation** is a required activity throughout the research process and only becomes a stage as the research draws to a close. It testifies of the efficacy and validity of the research outcomes, the completeness and accuracy of the data, the research process, and the quality of the team's performance. During the design of the research, the PI and the team will have identified success indicators that provide metrics for various elements of the research process. They will have chosen the appropriate instruments to measure and collect data, and they will have selected the appropriate techniques to analyze the data. This stage extends from early in the project until its end and periodically may redirect certain segments of the project. Final evaluation will measure the value of the project deliverables, but equally important, it will measure the quality of the research process and the collaborative effort.

**-Distribution** of the research findings among the team and outside the team will occur throughout the project, based on requirements and the project management. The findings, disseminated as preliminary or final, are expected to demonstrate an increasing confidence in their accuracy as the project progresses from beginning to end. How and when distribution takes place is generally defined during the research design and modified as needed during research execution.

Examples of distribution among the team include ideas generated during the research, progress reports, meeting minutes, protocol modifications, and preliminary and final data. Distribution among the team is part of team communication, and builds trust and collegiality, forming the basis of a strong collaborative experience.

Funding requirements may demand distribution outside of the team – such as a requirement to share with researchers who are not members of the team or to make findings publicly available. Outside distribution may also be driven by a desire among one or more team members to publish in professional journals or other publications. Also, applying for a patent could be a reason for outside distribution. Any dissemination of findings outside of the team will require a designation of author(s). Authorship and the criteria on which it is based is best defined at the beginning of the collaborative engagement.

## Perspectives From New Mexico Researchers

New Mexico is rich in collaborative research experience, having 3 national laboratories, 3 major research universities, other independent research institutions and private companies all engaged in research at various levels. Therefore, it was important to the NM Energy Manufacturing Consortium that the local perspective on this topic and relative key elements be captured in this paper. Toward that end, interviews were conducted with researchers from Sandia National Laboratories, Los Alamos National Laboratory, University of New Mexico, New Mexico Tech, and New Mexico State University; and the following summarizes those interviews.

In the interviews, we sought to gather from each participant their perspective relative to the following questions.

Question 1: What qualities are most relevant to you when choosing collaborative a partner?

Question 2: What practices have you observed during research collaboration that you believe work well to help the project succeed?

Question 3: In your experience, how were the collaborative project goals determined?

Question 4: Can you describe a successful process for selecting a project lead?

Question 5: What kind of technical or administrative assistance that would be of valued to you before and during the research project, and

Question 6: What are your experiences and thoughts on engaging in creative and interactive spaces.

**The participants' responses to the above survey questions revealed the following noteworthy perspectives.**

- Question 1 takeaway: The best collaborative partner is one that has both strong interpersonal and highly regarded technical skills.

With collaborators having such a broad range of experience, skills, and knowledge; it is necessary for their qualities to complement one another to successfully collaborate. Participants also mentioned a good collaborative partner should be clear about his interests, be honest, respectful, reliable, resourceful, enthusiastic and possess highly regarded technical skills. These characteristics help build mutual respect and trust between collaborators.

- Question 2 takeaway: Effective and regular communication, both written and verbal.

An important determinant of a successful scientific research collaborative project is the establishment of an effective system of communication early on through routine meetings via face to face, conference calls, or video conferences, throughout the project. A good system of communication includes a protocol for clearly identifying the participants' responsibilities, expectations, roles, as well as project time-tables and milestones for the different tasks and communication regarding the scheduling of meetings.

- Question 3 takeaway: The researchers' goals must align with those of the sponsoring agencies'; however, having the flexibility to negotiate goals is critical.

Survey participants identified that the practices used to determine a collaborative project goal commonly varies from industry to industry. However, when projects are funded through grants, the goals are typically defined by the grant sponsor. In certain contractual arrangements, goals can be defined by the research team, based upon the study being conducted and a targeted technology, The team's scientific disciplines, strengths, experience, and knowledge, may influence the strategies adopted to achieve the goals.

- Question 4 takeaway: The project lead is usually the **principal investigator (PI)** that identified and secured funding for the project. However, if there is an opportunity for the team to provide input in the selection process of the PI, the team who should make the decision as to who will lead the project.

In a collaborative research project, a project lead/principal investigator (PI) is most generally self-identified, due to their keen interest in the research opportunity and responsibility for submitting a successful proposal and assembling a team. The PI should possess the ability to bring people together and manage them, the vision to plan ahead, and be totally committed to the success of the project. Since the PI is accountable for the project's outcome, it should be recognized that taking a position as a PI bears a risk. It is not always a career booster. At times, a self-identified leader may be more comfortable in the role of team member. When this is the case, the team should select a more suitable PI from among the team.

- Question 5 takeaway: The technical and administrative assistance resources provided to the project should enable researchers to focus on conducting success research.

Assistance with grant writing, and the opportunity to transfer the management of the budget, schedule and deliverables, appeared to be a welcomed role(s). Therefore, project management assistance would be most useful in moving a project along and ensuring successful project completion.

- Question 6 takeaway: Participants seem to be open to engaging in creative and interactive spaces, some which take place at conferences, seminars, workshops, etc.

It may be time to consider some new ways to bring people together for creative thought and idea generation. The current spaces and processes may be insufficient to accelerate the amount of usable outputs and the time to achieve them. Although our interviewees agree in general, a few expressed some hesitancy.

**Please refer to Appendix to find the individual, survey participant responses.**

Some conclusions drawn from this study (literature reviews and interviews) are that research collaborations are most productive when:

- researchers are engaged, technically competent, relational, and committed,
- PI possesses good team support and research management skills,

- interests, goals, roles, responsibilities of each team member are well understood and defined,
- independent project management assistance is available and actively involved, and
- new means of inspiring creative thought should be considered if an accelerated volume of technical output is desired.

In summary, a successful team effort is the demonstration of the quality of contribution from the individual members. If each team member can contribute to the project to the fullest extent of their assigned role and responsibility, the collaboration will be successful.

## Basis for Design of ATC Process Map

### **To Collaborate, or Not :**

Collaboration is not always the answer and should be done only after assessing the project needs and goals. Risks, costs, and benefits must also be assessed before a collaboration is even considered. If the decision is made to collaborate, then identifying peers with whom to form a collaboration is the next critical step.

The project initiator (usually the Principal Investigator (PI)) unofficially assumes the role of recruiter and should adequately vet each potential partner. To the fullest extent possible adequate information should be sought about a candidate partner to understand their research interests, research and collaborative strengths, weaknesses, and related experience. The selection process should be a thoughtful and criteria-based one, because ultimately the project will succeed or fail based on a working relationship.

When forming a reasonable set of criteria for selecting a candidate, a PI can do well to consider demonstrated evidence of a candidate's:

- desire to handle assigned role and responsibilities - interest in pursuing a particular area of research with other investigators, and availability to serve in the project
- expertise in the required area - track record of research and publication in the desired area of specialty
- motivation to meet deadlines – one measure of competence in conducting research, is the ability to stay on schedule while maintaining the integrity of the investigatory process
- writing and speaking skills to author or present findings either at professional meetings or to the general media.
- complementary work style - compatible work styles can enhance the success of a collaborative partnership
- teaming skills - colleagues who treat each other with respect are more likely to avoid or resolve challenges or issues

The PI can identify potential candidates through a variety of means, such as, social media (Facebook, LinkedIn), peer referrals, conference proceedings, social networking events, by reaching out to past collaborative partners, and other ways.

### **In The Beginning:**

The collaborative environment should be favorable for all team members, and there are conditions a researcher may want to assess before a collaboration is established.

- o Will the environment be an empowering, respectful, and satisfying?
- o Will the environment be a place of physical, mental, and social wellbeing?

- o Will the environment provide a sense of professionalism, accountability, transparency, cooperation, efficiency, and effectiveness?
- o Will the environment ensure all parties have a say when making important decisions?
- o Will the funding cover the total cost of the design and implementation of the research?

If at any time, these conditions seem uncertain, a researcher might consider opting out or renegotiating the collaboration.

### **Establishing roles and responsibilities**

Collaborators should complement each other's knowledge, skills, and research outputs. In a collaboration, a team effort has been determined to be necessary, but it is important that each investigator's effort and participation stand out as an independent contribution to the overall team effort. It should also be established and communicated why each member is interested in the project, what each member's task(s) will be, and the amount of participation each member will have in the project. The above should be clearly communicated before the project begins or at least at the beginning of the project.

When establishing the roles and responsibilities of each member of the collaborative team, the following considerations should be made.

- Each investigator's role should be openly communicated when it is assigned, and the importance of the role and its tasks to the overall project should be clearly understood by other team members.
- Each team member's responsibilities should also be clearly defined and explained to ensure the individual understands and agrees to the terms. Additionally, the responsibilities should align with the individual's role, and stature in the project. This ensures accountability.

As the leader, the (PI) distributes and manages the roles and responsibilities, based on criteria and qualities described earlier. However, the PI can share some management responsibility with one or more lead investigators (Co-PIs). The shared management responsibility can include any number of activities that the PI and Co-PIs agree upon.

### **Designating authorship**

Authorship is a highly valued and expected outcome of research, but it can be a source of conflict if not addressed early in the collaboration. Ideally, criteria for assigning authorship are determined before the research begins. Care should be taken to ensure the criteria is measurable and performance against it can be clearly demonstrated. This will help avoid conflict and support a great end to the research project and collaboration. There are no standards for crediting investigators with a value to attribute to authorship, and guidelines for selecting criteria vary from institution to institution and among disciplines. Therefore, selecting measurable criteria is important and should be done in a manner acceptable and agreed upon by the entire team. Although there are some common practices for assigning authorship, the important thing is that everyone agrees.

Some common practices include:

1. Assigning the highest order and credit to the people with the largest contribution to the project,
2. Making the assignment based upon who is willing to take the lead in writing and/or coordinating the writing efforts of select team members, or
3. Assigning authorship and co-authorship can also be based on the following:
  - The first author is the individual who has participated in all of the following: (a) conception or design, analysis and interpretation of data, or both, drafting the article for critically important intellectual content; (c) final approval of the version to be published.
  - A co-author is the individual who has participated in two or more of the following: (a) conception or design, or analysis and interpretation of data; (b) drafting or editing portions or revisions of the article; and (c) providing the intellectual proposals for funding the project

Authorship can be reassigned or removed, based on performance and the agreed upon intellectual property rights. Since the authorship is negotiable, flexibility and cooperation should be maintained.

### **Preparations - The Unexpected and Conflict Avoidance**

It is difficult to manage the unexpected, but preparations should be made early in the project to develop a process to manage unexpected challenges. A PI will be wise to lead the research with good planning and consistent implementation. And a well-defined decision support process is advisable to help a PI manage the research process and prevent bottlenecks and misunderstandings.

Disagreements over authorship, intellectual property policies, budgets, surprise results that cause a change in the parameters of the research or the project design, or any other foreseen or unforeseen circumstances can cause conflict. Having an agreed upon conflict resolution plan (CRP) is suggested for all collaborative engagements and should be referenced during times of conflict or potential conflict. The decision support process can serve as an anchor for the CRP.

### **In The Middle:**

If the agreed upon terms and conditions for working together are not met as the collaboration proceeds, a researcher should consider opting out or renegotiating the collaboration. The researcher should communicate the perceived issue(s), propose the next steps, and document all proceeding agreements.

The most important measure in successful collaborations is ongoing, open lines of communication. Face-to-face, phone, e-mail, or letter communication among collaborators should occur frequently and are necessary for transparency in sharing findings, results, data, and any other important information. Silence in a collaborative research relationship is not welcome and can justify the termination of the collaboration.



Each party should be upfront about wants, needs, and their expected contributions for the project. When a team problem arises - real or perceived, the matter should be communicated openly and as precisely possible, with the intention of reaching a mutually beneficial solution. Such circumstance should warrant the use of the CRP.

The CRP will be effective if it can encourage each collaborative party to consider the following while working towards a resolution:

- Conveying their own point of view (whether about process or about the science) clearly and pleasantly.
- Listening respectfully to other team members.
- Tolerating the need to compromise and being frank about what they can live with and what they will not accept.
- Being open to considering the intervention of a third party, if a major problem arises

As the PI manages the process, it will become increasingly apparent that good leadership will be the key to success.

### **At The End:**

Some final steps may include the following:

- Documenting the conclusions from findings,
- Disseminating necessary information among the team,
- Returning all equipment and other resources per agreements,
- Completing grant termination requirements,
- Meeting expectations for outside distribution, and
- Celebrating a successful outcome.

Literature searches, case study reviews, and the responses from NM researchers will provide the basis for the first installment of the ATC process map which is now under way. New information and observations will warrant modifications to this paper and further inform the contents of the map. Finally, information from any source committed to improve the experience of collaborative scientific research is encouraged and will be welcomed.

## **The Vital Few**

Recalling the collaborative research goal stated in the preface, “... **to further scientific knowledge and create innovative technology for public benefit within a short period of time**”, the vital few best practices were found in the activities and situations distilled and documented from the literature searches, case studies and interviews. The analyses of the collected information helped conclude that these activities occurred to meet general objectives of a collaboration, which are necessary for successful research outcomes.

When research collaboration is important for a desired research outcome, the objectives of a productive collaboration appear to be:

1. Trust and support exist in the research environment
2. A formal research plan is developed and followed
3. Non-research tasks are managed by external support
4. Communication is frequent and efficient
5. Productive teamwork is realized

After the project objectives were identified, a list of vital few, best practices was selected:

1. PI exercises strong leadership skills (note: leadership is different from management, and includes shared research vision and expectations)
2. All investigators possess excellent technical skills
3. Team participates in formal planning sessions
4. PI documents a communication protocol
5. PI assigns clear roles and responsibilities
6. Project management is delegated to an accountable 3<sup>rd</sup>-party
7. Retreats, convened for the purpose of engaging in creative thought and ideas, occur at least once

## Closing

Collaborative research is powerful and necessary as the world meets the challenges of global warming, vanishing water sources, world hunger, deadly health pandemics, and other big problems. The power of collaboration lies in the ideas and technological outcomes that result from applying creative talent from many diverse scientific and engineering disciplines. Gifted scientists and engineers, working together toward a common goal will continue to solve our world's current and future challenges. These collaborative partnerships must be encouraged to accelerate applied research output that enables the production of advanced technology and new products. Improving and increasing these collaborations will benefit New Mexico and the rest of the nation, as they realize sustainable economic growth and continued improvements in quality of life.

Academic experts and economic reports, express confidence in the United States' ability to continue to be the leader in groundbreaking scientific research. And history recalls New Mexico researchers as having collaboratively engaged in research to solve some of the world's most critical and challenging problems, the greatest of which may have been creating weaponry to bring World War II to an end. The New Mexico legacy continues, and its collaborative research environment will play a critical role in producing innovative technology for years to come. The NM Energy Manufacturing Consortium seeks to leverage the collaborative environment to accelerate the innovation and technology output for manufacturing of products for the energy sector.

## Appendix

### All Interviews Conducted by Daniel Casas, UNM Senior, Mechanical Engineering

#### Survey Participant - ATC1

**1. What qualities are most relevant to you when choosing a collaborative partner? (e.g. discipline, institution, past partnering)**

An ideal collaborative partner is committed, exhibits good communication skills, and is cooperative.

**2. What practices have you observed during research collaboration that you believe work well to help the project succeed? (i.e., establishing communication line, rules, standards)**

In order to have a successful collaboration, the necessary resources, capabilities, and personnel must be available for the project. The selected personnel must also possess adequate technical expertise.

**3. In your experience how were the collaborative project goals determined? (i.e., delineating responsibilities)**

A collaboration's goals are decided by the entity paying the bills. The goals are usually stated in a proposal, where common ground between the researcher and the funding agency is explicitly stated. Once the proposal has been accepted; ground rules, deliverables, and goals are defined.

**4. Can you describe a successful process for selecting a project lead?**

When selecting a PI, work ethic, work history, attitude, and leadership qualities are all evaluated in potential candidates. Candidates should be willing to go the extra mile, have the desire to lead, comprehensively think through problems, possesses great communication skills, and have the leadership experience to know when to change course.

**5. What kind of technical or administrative assistance would be of value to you before and during the research project?**

Technical assistance needed for a project is dependent on the size of the project. For larger projects, the need for a project manager may be imperative. For smaller projects, this may not be the case. Administrative help is needed to ease communication between participants. Personnel with subject expertise provide technical help to draft a good proposal.

**6. What are your experiences and thoughts on engaging in creative and interactive spaces?**

Collaborative and creative spaces are important incentives for people to mingle, which may have a meaningful impact. Some of the best ideas and solutions have come to him during the time where he was among his colleagues outside of a work environment.

## Survey Participant- ATC2

**7. What qualities are most relevant to you when choosing a collaborative partner? (e.g. discipline, institution, past partnering)**

A partner must bring value to the team, in order to fill the gaps that may be present in a project. The most valuable qualities when choosing a collaborative partner are the ability to search for grants and funds for a collaborative project, networking skills, technical skills, ability to communicate and the ability to work well with others to build strong relationships. In business, a collaborative partner that possess networking skills is very important when they can facilitate in attracting others to join a project collaboration.

**8. What practices have you observed during research collaboration that you believe work well to help the project succeed? (i.e., establishing communication line, rules, standards)**

Collaborative projects that are well organized, using timetables, and milestones.

Developing good communication plans at the beginning of the project to search for additional qualified people and to ensure the project meets the goals and objectives. Being committed to finding people with the right skill set. Leveraging previously established relationships to help ensure trust and to provide a certain level of comfort in communication.

**9. In your experience how were the collaborative project goals determined? (i.e., delineating responsibilities)**

Most of the time in academia or privately funded projects the goal is to find money. Agencies tell you what they are looking for by providing guidelines and examples of previous contending proposals on a website. There must be fluidity in establishing goals because the collaborative project goals must overlap with the interests and goals of the funding entity. . Once an idea is defined that overlaps with funding entities, the team should seek to clarify the game plan and the goals necessary to approach the funding entity.

**10. Can you describe a successful process for selecting a project lead?**

A project lead may be determined by who is paying for what. To begin with the person who put everything together will be assigned as the project lead. This does not mean that they remain the project lead, as the team is able to select a new project lead that better suits the teams need. This off course must be allowed by the initial project lead. A good project lead has the ability to plan ahead, think broadly, communicate effectively, and talk tech. A person who has been in the project since day one may be more likely to succeed because of the depth of knowledge they possess about the project. These skills together are more important in a project manager, than superior technological expertise.

**11. What kind of technical or administrative assistance would be of value to you before and during the research project?**

Administrative support would be useful to make sure that everything is being done successfully within the bounds set by the funding agencies.

In addition, administrative support would provide value by conducting budget analyses, milestone reports, possessing market and grant expertise, and building relationship networks. Technical support would be valuable if facilitates concept development that emerges from industry input and leads to investment money or identification of CEO talent.

In essence, the assistance would be welcome if it contributes to the success of the researchers, the project deliverables, and any industry partners.

**12. What are your experiences and thoughts on engaging in creative and interactive spaces?**

No substitute for face to face. However, because everybody is busy and a team can be put together incrementally, an interactive space is helpful for certain types of meetings.

Collaborative spaces, that are driven by a goal and a purpose, and have communicated those goals and purposes to all of the participants could be very useful.

**Survey Participant- ATC3**

**1. What qualities are most relevant to you when choosing a collaborative partner? (e.g. discipline, institution, past partnering)**

The most important qualities in a collaborative partner are mutual trust, and respect. An ideal collaborative partner is a team player, has similar backgrounds and culture, and possesses complementary expertise. Collaborative partners should promote positive synergy between each another.

**2. What practices have you observed during research collaboration that you believe work well to help the project succeed? (i.e., establishing communication line, rules, standards)**

A preferred practice is a routine face to face meeting while also keeping in touch through emails or phone calls to keep the communication lines open.

During the beginning of the project expectations, roles, and deadlines should be clearly communicated. Ambiguity in any of these topics may result in problems, such as false expectations.

**3. In your experience how were the collaborative project goals determined? (i.e. delineating responsibilities)**

Goals are determined by a sponsor, and their mutual interests. They usually specify the goals in the proposals. Some goals are mutually agreed upon.

**4. Can you describe a successful process for selecting a project lead?**

A PI should have the ability to bring people together, and motivate people, and be able to deal with different types of personalities. They should also be able to define future goals and objectives and communicate clearly. They should have a firm understanding of the project and be able to facilitate the work of others. Other characteristics usually found in a PI are research skills that are held in high regard, is respectful and fair, good people skills, and is experienced.

**5. What kind of technical or administrative assistance would be of value to you before and during the research project?**

A project coordinator usually takes care of all of the paperwork and talks to all appropriate personal to set up meetings, and other administrative tasks.

A crucial technical/administrative position during a project is a lab coordinator/Senior Scientist. A person who can run the lab - day to day, communicate clearly with researchers, and can present the lab to visitors.

Another example of administrative support that may be needed is a social media lead. A person who helps have promote presence inside social media platforms.

**6. What are your experiences and thoughts on engaging in creative and interactive spaces?**

No substitute for face to face. Willing to participate in interactive spaces. Creative spaces are enjoyable. Had some personal experience working at google in non-conventional workspaces. Willing and enthusiastic about participating in similar work environments.

**Survey Participant- ATC4**

**1. What qualities are most relevant to you when choosing a collaborative partner? (e.g. discipline, institution, past partnering)**

One of the most desirable qualities in a person is leadership, so that they may provide guidance throughout the project. Their leadership must be present in tasks like running their own lab, and guidance of students. Another desirable characteristic is the drive to generate ideas for a proposal, showing that they be able to contribute their own unique ideas and perspective to the project. Having people like this in a project, leads to multiple people contributing intellectually to the current and potential research work. Taking initiative in proposal writing, generating ideas, research, publishing, having good track record are all important.

**2. What practices have you observed during research collaboration that you believe work well to help the project succeed? (i.e., establishing communication line, rules, standards)**

Recurring constructive interactions, that add value to the project. These interactions must provide the opportunity to connect and tie pieces together across the research. Meetings may take the form of planning or participating in brainstorming sessions. These types of meetings should be prevalent during the beginning stages of the project so that people may be able talk about the research and potential ideas. Face to face opportunities should be present throughout the project as much as possible and they may be conducted yearly, or quarterly. Monthly meetings among the

PI's can keep the research moving forward. Supplementary, weekly or monthly meetings should be conducted to provide meaningful interactions across the entire team, from the PI's to the grad students involved. This helps engage the grad student in the research.

**3. In your experience how were the collaborative project goals determined? (i.e. delineating responsibilities)**

The project goals are regularly determined by the person who put the team together, and that usually is the lead PI, but is not always the most effective way to determine project goals. Alternatively, project goals may be determined progressively over a series of recurring meetings with people, that lead to crafting a path forward. This process may also help determine how to achieve the project goals, and how to work through challenges.

**4. Can you describe a successful process for selecting a project lead?**

In most instances the project lead is the person who brings the idea to the table but may not always be the most effective leader. If the leader turns out to be unfit, an intermission is held by the team to identify a suitable leader to ensure a successful project. (Note: In 70% percent of the project, the interviewee had been on, the initial PI remained the PI.) In some instances, groups of people come together to obtain the funding, and people are willing to pull together to get the funding, even if the PI is not the strongest leader. This could be seen as a level of collaboration that is non-confrontational.

In other instances, a PI may be selected because of their credentials or based on contextual opportunity regarding agencies and their interest. Overall leadership is an opportunity and can be a cause of a misguided perception of what that opportunity can mean for a researcher's career. This unfortunately leads to unfit project leaders on many projects.

Most unfit project leads produce weak proposals, and do not receive the funding they apply for. If a leader is technically weak, this can cause their underlings to carry an unreasonable technical burden. During a project with an unfit leader, it may be difficult to report back to the sponsoring agencies with a proper report of what is being done, and what the plans are moving forward. Most of these projects do not get extended nor do they replace the project lead.

**5. What kind of technical or administrative assistance would be of value to you before and during the research project?**

Some technical or administrative work that could be taken away from a PI is completing current and impending research summaries or reviewing CVs. This allows the PI to focus on the technical content.

While drafting a project proposal, someone who possesses good external context would be useful for putting the research into perspective, so that the sponsoring agencies understand how the research fits into their interests. This type of technical help may be difficult to obtain. It would also be useful to have someone cultivate a research network to help a researcher understand how their work fit into the scientific community.



Someone technical/administrative who can perform a final review of the proposal to provide constructive criticism, identifying which parts were done well, and which parts would not be valuable.

The most helpful administrative work for the PI is budget analysis, and the managing of the reports coming from and to the subgroup. In addition, the development of an effective structure for meetings that engage all levels of researchers, while also taking into consideration the frequency of meetings. Monthly phone calls that include everyone may be the best way to do it.

Other useful support skills and activities include graphic design, technical writing, and background literature review.

Fundamental science is research (6.1 research, basic science, standard academic research), whose applicability is within a 15-year horizon. It is usually funded through a grant, which does not have many formal reporting, and responsibility requirements through the research. Because the PI nor the funding agencies have control over what is done, the researchers usually indulge in poor work habits. Within government funded projects there is more explicit structured deliverables.

**6. What are your experiences and thoughts on engaging in creative and interactive spaces?**

Creative and interactive spaces are useful for developing collaborative ideas but must offer something meaningful so that the meeting is productive. Meetings in creative spaces may be useful for proposal writing, as people can break up into groups and write down different ideas to later share them with one another. Interactive virtual spaces are useful for teaching online classes or remotely conducting a presentation, but the technology associated with virtual interactive spaces may sometimes be distracting, hence making it counterproductive.

**Survey Participant- ATC5**

**1. What qualities are most relevant to you when choosing a collaborative partner? (e.g. discipline, institution, past partnering)**

The most important qualities a collaborative partner should have are professional expertise, aptitude, drive, and motivation, and clarity about what they are most interested in when taking part within the collaboration.

**2. What practices have you observed during research collaboration that you believe work well to help the project succeed? (i.e., establishing communication line, rules, standards)**

A project will succeed if team members are motivated to make the project succeed. A major drawback to a project may be team members that are indifferent to the project's success. Good communication that addresses goals and setting priorities, and involves intermediate steps such as meetings that provide guidance for upcoming tasks.

**3. In your experience how were the collaborative project goals determined? (i.e., delineating responsibilities)**

Collaborative goals are determined at the beginning of a project or during the drafting of a proposal. These goals are determined by the individual members strengths. During the project, collaborative goals may be changed because things are not going as planned, and it is the PI's job to reorganize project goals.

**4. Can you describe a successful process for selecting a project lead?**

Would like to select a project lead based on a combination of expertise, knowledge, and soft skills. Soft skills refer to the necessary attributes a person needs to lead, for example people skills. When unilaterally selecting a project lead, one must seek and include people's input.

**5. What kind of technical or administrative assistance would be of value to you before and during the research project?**

Some technical assistance that may be needed before the project begins are the preparation of forms, document collection (keeping track of existing publications, or biographies) and setting due dates and deadlines. During the project administrative work like tracking deadlines, spending, purchasing, budgeting, and overall financial analysis would be helpful.

**6. What are your experiences and thoughts on engaging in creative and interactive spaces?**

Creative and interactive spaces are very important because they promote thinking outside of the box and can provide a way of breaking out of the usual expertise of a 9 to 5 work experience. May provide the opportunity mingle with other people with different fields that may extended to arts and humanities.

Had some experience at UNM that involved the departments of engineering, management, and the international film and digital media department. The project took engineering data and created a series of animated episodes about renewable energy. A similar project used data detailing where solar energy was provided, and LED lights to visually represent the locations.

Experience with virtual office hours, over google hangouts for online students, and participation in projects that require virtual interactive spaces. increases the willingness to participate in any project that involves virtual interactive spaces.

**Survey Participant- ATC6**

**1. What qualities are most relevant to you when choosing a collaborative partner? (e.g. discipline, institution, past partnering)**

The most important characteristics in a collaborative partner are commitment, resourcefulness, complementary expertise, honest communication, and a successful work history in multidisciplinary projects.

**2. What practices have you observed during research collaboration that you believe work well to help the project succeed? (i.e., establishing communication line, rules, standards)**

During a research collaboration a team should define standards for the team's quality of work and collaboration. Standards would help within a meeting Structure to communicate the importance of preparation that leads to meaningful contribution and may help the participants understand the overall scope of the project. For example, a level of commitment should be expected from a researcher when conducting a meeting. So, the researcher feels the need to prepare for the meeting and can then contribute meaningfully. A structure between sub-teams should be established to communicate and facilitate collaborative contributions. When assembling sub teams, a PI should attempt to group people together of different disciplines to break people out of their state of comfortability.

**3. In your experience how were the collaborative project goals determined? (i.e., delineating responsibilities)**

To begin a project, something must serve as inspiration to drive researchers to work. Sometimes project ideas arise spontaneously within conversations, and a goal comes along the way. Within these types of projects, the goals are determined through trial and error and along the way. One must define some goals then ask which goals are necessary. Ideas and goals must overlap with funding agencies to obtain funds for the project. In addition, research groups should have a persistent intent to want to jump at an opportunity, rather than congregating together in response to an opportunity.

**4. Can you describe a successful process for selecting a project lead?**

A successful project lead must integrate different personalities and members together within sub teams. They should have a general understanding of how individual subgroups contribute to the project.

**5. What kind of technical or administrative assistance would be of value to you before and during the research project?**

Administrative help that an institution could provide is the commitment to breaking down barriers and assuring paperwork necessary to perform tasks is in order. Providing a facilitator that can push people to work together, to encourage cross disciplinary work, and keep people from getting hung up on technical details. Another potential asset to a team is having an advisor whose purpose is to suggest technical material and provide ideas for a potential project proposal. This may ease the process of drafting a proposal. Overarching project structure, in terms of budget and organization are needed as administrative support.

Experience in how to build a story, for a proposal is important for formulating a strong proposal.

**6. What are your experiences and thoughts on engaging in creative and interactive spaces?**

Interactive virtual spaces have improved connectivity and may someday replace an in-person meeting. An interesting concept that could potentially materialize is an interactive space for labs.

During research, the interviewee has a slight preference to tend to stay very isolated to work on separate tasks related to independent profession. Interestingly enough, students are pushing them to work on multi-disciplinary projects. Most likely because they are accustomed to having social interactions with people in different disciplines.

### **Survey Participant- ATC7**

**1. What qualities are most relevant to you when choosing a collaborative partner? (e.g. discipline, institution, past partnering)**

There should be a level of enthusiasm for the project and chemistry among support groups with technical and subject matter expertise. Once a team has the aforementioned qualities, the team should include a span of ages and experience. The team should seek out institutional support that is necessary for recruitment, retention, exercising capabilities, and expanding capabilities. Another consideration is the possibility of the creation of Intellectual property (IP), so that mutual agreement between the researchers and institution may come about. The documentation of a CRADA is usually what occurs and is usually in the interest of promoting IP creation for the benefit of U.S. industrial growth.

**2. What practices have you observed during research collaboration that you believe work well to help the project succeed? (i.e., establishing communication line, rules, standards, and delineating responsibilities)**

At the beginning of the project, the administrative and technical sides meet to discuss and agree on the research question that will drive the project. The researchers agree on the project's goals and objectives. Once that has been established, the project may be analyzed from a project manager's point of view. Project specifics should be identified- roles, meeting, project schedules, resources, risk mitigation, and other standard project management details. The most successful project usually adopts a scheduled routine meeting over the phone, to exchange information. In addition, emails, and phone calls are also regularly conducted between team members. This communication allows the project leads to have adaptive responses to the status of the project in the form of immediate and future plans. Another practice that may help researchers is to know when to quit and identify the project may not work. This can occur during the formulation of the goals, objectives, and the research question. The best possible outcome of a collaborative project is a patent for the company, and a peer reviewed publication for the researchers.

**3. In your experience how were the collaborative project goals determined? (i.e., delineating responsibilities)**

A researcher will dissect the research questions and its challenges in order to search for common interests with a funding agency. Once a collaborative relationship has been established, then the deliverables of the project are defined.

**4. Can you describe a successful process for selecting a project lead?**

Most project leads are self-identified. This is accepted because the scientific community is small, which means everyone is familiar with one another, and they more than likely to trust one another's judgments.

USDOE calls for team assembly in the form of a consortia, that may then turn into a CRADA. These opportunities are usually obtained through a formal process of submitting a proposal.

**5. What kind of technical or administrative assistance would be of value to you before and during the research project?**

The objective of providing administrative services is to allow researchers to focus on the science of the project. Administrative task that can be provided for the researchers are the filing of patents, the management of the relationships with the companies and management of communications.

**6. What are your experiences and thoughts on engaging in creative and interactive spaces?**

Question 6 was not covered in this interview.

**Survey Participant- ATC8**

**1. What qualities are most relevant to you when choosing a collaborative partner? (e.g. discipline, institution, past partnering)**

Multi-disciplinary projects are necessary, to solve complex engineering problems.

Understanding of how to solve a complex system

The most important traits in a collaborative partner are passion, enthusiasm, and the ability to apply knowledge to practical applications (Technical skills). The passion to dive into their field of work and strive to expand their knowledge and understanding for themselves and the industry. It is productive and pleasant to work with people that are reliable, possess high technical skills, are adept in the use of tools, demonstrate common sense, are self-aware, cautious, quick learners, and possess strong engineering fundamentals. Along with these characteristics and skills, modesty must be one of their most defining qualities.

**2. What practices have you observed during research collaboration that you believe work well to help the project succeed? (i.e., establishing communication line, rules, standards)**

The premise of the project must be realistic, practical and must be grounded on scientific findings. In addition, an organization (institution) should fully support a research project for optimal results.

**3. In your experience how where the collaborative project goals determined? (i.e. delineating responsibilities)**

Project goals may be determined through communications between the companies and researchers to identify the common interest the project encompasses. In other instances, project goals are determined by the proposals, and by the funding agencies the proposals are submitted to.

Sometimes proposals may be created with the help of a group of people with their thoughts and

ideas, and in general, people are most often very open and willing to collaborate when asked or approached for the purpose of collaboration

**4. Can you describe a successful process for selecting a project lead?**

A PI is usually the person who identifies the collaborative project opportunity. Alternatively, a group of people may come together around an idea or project and may then decide to elect the most suitable PI among the group.

**5. What kind of technical or administrative assistance would be of value to you before and during the research project?**

Administrative help is needed to search for new opportunities, oversee funding, format research, managing organizational and communication tasks. For example, setting up meetings, taking note during those meeting, and communicating the outcome of the meeting to the appropriate people.

**6. What are your experiences and thoughts on engaging in creative and interactive spaces?**

Interactive and creative spaces are not used within the petroleum community, because of the nature of the work associated to the industry. They do however interact with one another through conferences. It is important to meet and have meaningful interactions with people who are going to be involved in the project.

**Survey Participant- ATC9**

**1. What qualities are most relevant to you when choosing a collaborative partner? (e.g. discipline, institution, past partnering)**

Communication is the most important skill. Without communication skills, all other skills can be difficult to take advantage of. Make people comfortable by placing them in areas they like and can contribute well, based on their backgrounds.

**2. What practices have you observed during research collaboration that you believe work well to help the project succeed? (i.e., establishing communication line, rules, standards)**

Splitting up a project into groups, tasks, objectives, and placement of individuals into proper groups based on skills and backgrounds. Employing a divide and conquer tactic to separate paperwork from scientific study. Having someone whose job it is to take care of ADMINISTRATIVE tasks helps productivity. The administrative sides job is to make everything work.

**3. In your experience how were the collaborative project goals determined? (i.e., establishing communication lines)**

Aces in their places, adjust people accordingly to their strengths. It is important to explicitly define why participants should complete their project tasks. Deliver a clear message that communicates

why the work they have been entrusted to work on is important not to them and to the project. Do not overburden people; assure that workers have been assigned a proper amount of work. A researcher should be wary of the work load they accept and collaborate with the administrative side/superiors to manage the workload.

**4. Can you describe a successful process for selecting a project lead?**

A project PI must be able to put the project together by selecting individuals and organizing communication lines between researchers. They should Select people based on their work history (eg. previous projects, technical experience), and the PI can hand pick people to work on certain tasks. Anyone who is interested is contributing to the project should be selected based on skills, ability to communicate, previous experience, and how they contribute to each part of the project.

**5. What kind of technical or administrative assistance would be of value to you before and during the research project?**

Knowledge of the administrative side of the project and the people who oversee scientific process. Before the project begins, the administrative and technical sides should be able to determine the project budget allocation and define the objectives. The administrative function can manage paperwork, oversee a project and create a timeline, deliverables, and budget. Meetings should be regulated, because overcommunication can be counterproductive. And if that is the case, reducing the number of meetings will improve productivity.

**6. What are your experiences and thoughts on engaging in creative and interactive spaces?**

Interactive workspaces can be a distraction; productive people can become distracted by things that may seem fun. A definite separation between work and the interactive spaces is needed to be productive.

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