ALLAN J. ACOSTA
(1924–2020)

INTERVIEWED BY
SHIRLEY K. COHEN

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ARCHIVES
CALIFORNIA INSTITUTE OF TECHNOLOGY
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Subject area
Engineering

Abstract
An interview in four sessions, in April and May 1994, with Allan James Acosta, Richard L. and Dorothy M. Hayman Professor of Mechanical Engineering, emeritus, in the Division of Engineering and Applied Science. Acosta received his undergraduate and graduate education at Caltech (BS, 1945; MS, 1949; PhD, 1952). He joined the Caltech faculty in 1954 and became a full professor in 1966 and Hayman Professor in 1990. In this interview, he discusses growing up in Southern California during the depression and his early interest in science and engineering; his war service in the U.S. navy, including the navy's V-12 program at Caltech, and his observation of the first A-bomb blasts at Bikini Atoll. After his discharge from the service in September 1946, Acosta returned to Caltech and was hired as an engineer by R.T. Knapp, head of Caltech's Hydraulic Machinery Laboratory, which was then testing pumps developed by the Byron Jackson Co. of Los Angeles for Washington State's Grand Coulee Irrigation District. After a year, he became a graduate student. He discusses the Hydraulic Machinery Laboratory, established by Knapp in the early 1930s, the establishment of the related Hydrodynamics Laboratory during the war, its evolution under Milton Plesset, and its connections with the Guggenheim Aeronautical Laboratory (GALCIT). He discusses his work in fluid mechanics and heat transfer and his

association with mechanical engineering colleagues Rolf Sabersky, Duncan Rannie, Frank Marble, and Edward Zukoski, and later with Christopher E. Brennen. He discusses the history of GALCIT, and his work for the Fluids Engineering Division of the American Society of Mechanical Engineers [ASME]. He comments on the evolution of the Division of Engineering and Applied Science at Caltech. The interview closes with reminiscences of some of his PhD students.

Administrative information

Access

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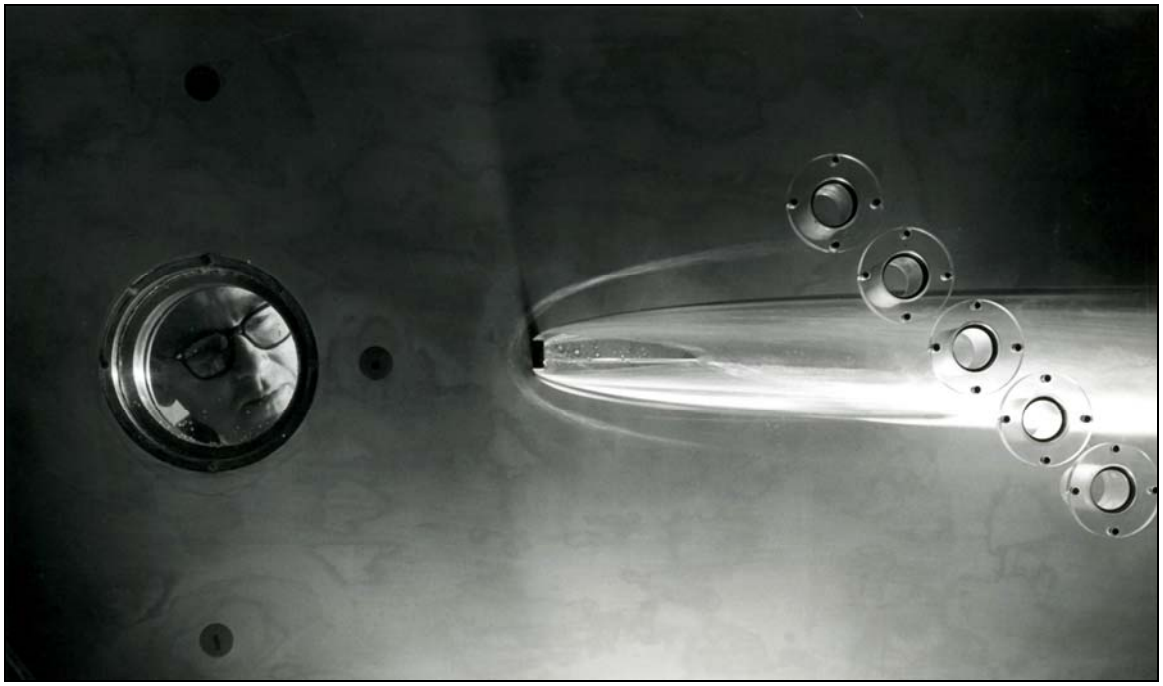

Allan Acosta observes a cavitating flow in a section of high-speed water tunnel in Caltech's Hydrodynamics Laboratory in the mid-1960s. This study involved the testing of hydrofoil boats for the U. S. Navy. Original photo published in *Engineering & Science*, February 1965. Used by permission.

CALIFORNIA INSTITUTE OF TECHNOLOGY ARCHIVES

ORAL HISTORY PROJECT

INTERVIEW WITH ALLAN J. ACOSTA

BY SHIRLEY K. COHEN

PASADENA, CALIFORNIA

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TABLE OF CONTENTS

INTERVIEW WITH ALAN J. ACOSTA

Session 3

Session 4

CALIFORNIA INSTITUTE OF TECHNOLOGY ARCHIVES
ORAL HISTORY PROJECT

Interview with Allan J. Acosta **by Shirley K. Cohen**

Pasadena, California

Session 1	April 21, 1994
Session 2	April 27, 1994
Session 3	May 3, 1994
Session 4	May 19, 1994

Begin Tape 1, Side 1

COHEN: You grew up in the Los Angeles area. Can you tell us a little bit about that?

ACOSTA: Yes. I went to David Starr Jordan High School in Long Beach, and I graduated in 1942. At that time, since I knew nothing about engineering, I was interested in becoming a chemist.

COHEN: Let's go back a little bit. Tell me about your parents. What did your father and mother do?

ACOSTA: My father was a machinist when he was onshore. He worked on the Metropolitan Water District's pump aqueduct, which was one of the few jobs during the Depression. When he was not onshore, he was the chief engineer on ships, having been in the navy in World War I and on merchant ships subsequent to and during World War II.

I was born in Anaheim, as the record shows. We lived in the area, in various places where my father's work took him: Beaumont, Banning, Hemet. But the oil fields were the source of work onshore for people who did machine work and had some general knowledge of machinery, as he did. Life was quite different in the Los Angeles area, in Southern California,

than it is now. In lots of ways, it was better.

COHEN: Not so many people.

ACOSTA: Not so many people, more agriculture. The denseness of housing we are now experiencing was completely different. Lots were big; there was plenty of open space, and that was much more pleasant to be growing up in.

COHEN: Were your parents born in California?

ACOSTA: No, my father is a Floridian. My mother was born in Kansas. My father comes from a family that was in Florida for many, many years—before Florida became a state, even. In fact, I don't have any relatives I know of who came to this country after the Revolution, both my East Coast and my Florida ancestors. So that's a bit unusual.

COHEN: That's correct. Now, is "Acosta," a Spanish or an Italian name?

ACOSTA: It's both. It's a Mediterranean name. Portuguese, Spanish, Italian, Greek all have a name that means the same thing.

COHEN: And that is?

ACOSTA: "From the coast." In those times, in Long Beach before the war, we were the only Acostas in the phone book, as opposed to now.

COHEN: There are many now?

ACOSTA: There are many, many, many now, yes, due to the migration of people primarily from Mexico and Central American countries.

I don't really know where my ancestral parents came from in the Mediterranean.

COHEN: And your mother?

ACOSTA: She was born in Liberal, Kansas, which is not far from Topeka. My mother's father was a Methodist minister in the Kansas area and then later in Florida.

COHEN: Did your parents meet in Florida?

ACOSTA: Well, no, they did not. My mother met a relative of my father's. My father ran away from home and joined the navy when he was young and never returned to Florida. That was not uncommon in those days. My mother's parents moved to Anaheim just before World War I. By that time, through relatives, my mother and father got together, and that's where I was born—in Anaheim, not far from a citrus grove.

COHEN: It was just a farming community then.

ACOSTA: It was a farming community then, and a very pleasant one. It's a different world now. Orange, Santa Ana, Anaheim, all very agricultural. Very pleasant.

COHEN: So you grew up there and went to school there.

ACOSTA: Went to school in various areas. Following my father's work. The Depression was very hard here in Southern California. I don't know if you were around then or not.

COHEN: No, but we've all read *The Grapes of Wrath*.

ACOSTA: Yes, you've all read *The Grapes of Wrath*. I remember, astonishingly, seeing huge piles of oranges being burned because they could not be sold; there was no market for them. Other than being burned, they were given away to people who had nothing to eat. There were lines for soup kitchens in Los Angeles. Shipbuilding was down. Oil production was down. And there wasn't much else, because nothing else could be sold. So it remained that way, except for the Metropolitan Water District's aqueduct from the Colorado River, which was the one large engineering project. And that made a big impression on me as a kid, because it was the only thing to do.

Things like the WPA [Works Progress Administration] and so on, which came on after

Roosevelt was elected in ’32, made a big impact locally, because they gave jobs to people who had none.

COHEN: Did you ever meet Mr. [William] Mulholland?

ACOSTA: Well, I knew of him. But he had nothing to do with the Metropolitan District. That was the northerly water project from the Sierras for the Los Angeles Water and Power District.

The failure of the Mulholland Dam, the San Francisquito Dam, did affect the other side of my family, my wife’s family. My father-in-law at that time was a construction engineer, and his job was to survey part of the damage from the San Francisquito Dam disaster. At that time, he had a ranch on the Santa Clarita River. The people who worked the ranch for him lost a child in that flood.

COHEN: So then, coming back, you were born and went to school in this area. When did your interest in science or engineering come?

ACOSTA: Oh, well, science first, because that’s what you have available to you. I remember in the fifth grade going to the local library, and apart from reading kids’ books, I checked out books on science and read avidly. More interesting than the fiction reading. The things you’re exposed to, of course, are physics and chemistry and mathematics. Chemistry and astronomy seemed to me to be just wonderful.

When the start of the 200-inch [telescope] project [at Palomar] occurred, why, that was really exciting.

COHEN: That was publicized throughout the area?

ACOSTA: Yes it was. The *LA Times* had a photo section, of course. It was really big news. There was Mount Wilson already, and then the Hale telescope really was an exciting thing. That and the Metropolitan Water District, also a very big thing.

But I was always interested in science and engineering, as I knew it at that time. I had no doubt, by the time I was in junior high school, that I would be in one or the other. Things like medicine and so on, for some reason, just did not appeal to me.

COHEN: Were you encouraged by your father?

ACOSTA: Well, I guess so. It's kind of hard for me to remember now. He was a bit remote. He worked very hard. Those were anxious times for parents, because there was very little money to go around, and there were times when we were actually physically hungry. We lived on simple food. No extras whatsoever.

Starting during the Depression, when we lived in Hemet, I worked every summer as best I could, in fruit cutting and drying sheds, things of that sort. I remember that the summer before the sixth grade, I made $15. At that time, my father was making something like $30 a month. It's inconceivable for most of us to appreciate what those numbers meant. For $15, I was able to buy a year's worth of school clothing. So from then on, I and everyone else I knew worked summers to help support the family. Everyone I knew in high school worked part-time jobs, paper routes, anything they could do, and I was no different.

COHEN: Then I see you got your degree from Caltech in '45 and you went into the navy, I believe. Is that correct?

ACOSTA: Yes. There was a special program called the V-12 program. But I do remember after war broke out in 1941, the next week or so, I went to sign up for the officer-training program. The navy base at that time was where Dodger Stadium is now. We all signed up for that and graduated from high school. And in 1942 I went for a year or two to what was then the Long Beach Junior College, because the V-12 program had not been implemented yet.

COHEN: So did they take you when you signed up and then tell you to continue with your schooling?

ACOSTA: They did. That's precisely what they did. We continued with our school work with no change, no duties. I did not sign up for the draft when I was eighteen.

COHEN: Because you were already in this program?

ACOSTA: Yes. So I went through one year at Long Beach Junior College. The level of

instruction there wasn't like what it was at Caltech. Then the V-12 program started, I think, in July, 1943. It was amazing for me to realize that when I officially retired as of July 1, 1993, last year, that was exactly fifty years ago.

COHEN: Did you know you would be sent to Caltech?

ACOSTA: No, I had no idea, no idea whatsoever. You were just assigned. The V-12 program was for engineering, not so much science. You had your choice of mechanical, civil, or EE [electrical engineering]. I think those were your three major choices. Options in chemistry and so on, there were very few of those.

The idea was to become an active duty officer in the navy, serving in some engineering function or deck function. We were training for the most part to be engineering officers but to be on active duty on ships or bases or whatever. So in that respect it was quite a remarkable program. I heard there were almost a hundred thousand people across the country in that program.

COHEN: How did a school like Caltech get to be included in the training part? Did it volunteer to do this kind of work?

ACOSTA: I don't know all the particulars of that. I think the school contracted with the service to do something like this.

There was a somewhat parallel program for the army, called the ASTP, Army Special Training Program. It was the same idea, except the army was fighting a hot war, and most of the ASTP students were pulled out after about a year, during the Battle of the Bulge. But the navy program went on through. We went full-time to school, and unlike classes today, our first class was at eight o'clock. We got up at six, formed in platoons and marched to Tournament Park; we ran around the park three times and then marched back.

COHEN: How many people were here?

ACOSTA: I think there were five hundred. They were all boarded in the old houses [the resident student houses].

COHEN: On the campus?

ACOSTA: On the campus. Rooms that would normally have one person had two people and double bunkbeds. I think I stayed in D1 [Dabney 1], which was normally a two-person place. We had four people in D1 with little desks—little navy desks.

COHEN: Now, those would have been the buildings on the old San Pasqual Street that used to go through [the campus]?

ACOSTA: Well, they were the old original student houses: Dabney, Blacker, Ricketts, and Fleming. We were in Dabney. Those houses have been upgraded somewhat, but they were fairly new then, so they were quite nice. We thought they were wonderful, and they were completely different from boot camp. We had amenities.

COHEN: Did this happen after boot camp?

ACOSTA: No, we did not go to boot camp; we came directly here, to Caltech. So our military indoctrination, such as it was, was all done here on the Caltech campus.

The faculty who were still here taught the normal classes in social studies, math, physics, chemistry, and engineering. And so I didn't feel bad about being in mechanical engineering. That was the group that I guess I was either selected for or chose or was ordered to, I've forgotten which. But it certainly fitted me and it fitted my interests. I knew about engineering from my father's marine engineering work.

COHEN: Now, the people who were here, were they mainly Californians, or did they come from all over?

ACOSTA: Some came from all over, but they were for the most part Californians. You'll find in the Caltech history that the entire football team from Stanford came. The other members of the league in this area, USC and UCLA, still played, but most of their people were in the service. So the people who were left at USC and other universities around here I guess were not in good shape. But here we had the first-class varsity team from Stanford as part of our V-12 program.

COHEN: They came as a group?

ACOSTA: They came as a group to the V-12 program. Plus other people who were not on the football team.

COHEN: That sounds curious. It sounds a little pre-arranged.

ACOSTA: It was curious. If you look at the records—I think it was 1944—the Caltech football team was unscored upon, or some fantastic record like that. It was the best in the nation. And so, yes, there were people from other parts of the country, but most of them were from California. We had no choice; we were just sent to wherever the nearest V-12 school was.

COHEN: I see. They tried to send you somewhere close by.

ACOSTA: I presume so. There were not all that many V-12 schools; enough, though, to make up the whole program. I've forgotten the number.

COHEN: All over the country.

ACOSTA: Over the whole country, yes. It was a very good program. The courses were sort of Caltech courses, and they were taught by famous Caltech professors.

COHEN: Do you recall who some of the people were who taught you these courses?

ACOSTA: Oh, gosh. [William] Pickering gave physics lectures.

COHEN: Now, people like [C. C.] Lauritsen [professor of physics and director of Kellogg Radiation Laboratory, d. 1968] were very busy.

ACOSTA: They were very busy with their own projects. There were both Lauritsens, Charlie and Tommy [professor of physics, d. 1973]. I think Charlie Lauritsen helped out with the teaching of the senior physics people, but they were very busy with the war work. Abe Zarem taught

sophomore physics and formed Electro-Optical Systems—very colorful, wonderful guy. We all loved him as students. Morgan Ward taught mathematics. I remember a number of teachers in humanities. We didn't have social science then, just humanities it was called. I had courses from Clinton Judy, George MacMinn, [Paul] Eaton. And they were all very sophisticated for a kid from Long Beach who knew nothing about any of these things.

COHEN: That's interesting that you did have a humanities part in your program.

ACOSTA: It was exactly the same as the normal Caltech program, except maybe the intensity of the courses from the mathematics side was not as high, because we were not as well prepared as the Caltech students were.

COHEN: Were there Caltech students here as well?

ACOSTA: Yes. Some of them transferred into this program—those who could. Some of them didn't. Some of them were drafted before that time. But there were previous Caltech students here, and those few remembered the traditions of the various houses. So there were Dabney teas, and Ricketts was always getting into trouble, and Fleming was always different.

There was a military regimen in the houses. We had to get up as platoons. Ten o'clock, lights out. If you wanted to study, you had to go to a library.

COHEN: You were not housed with the regular students.

ACOSTA: No, the navy contingent occupied the present old student houses—Fleming, Blacker, Dabney, and Ricketts. And the same people ran the services for the houses as for the former Caltech students.

There were some civilians who lived in Throop, or used the old Throop as their center. There were graduate students who were civilians still, a few of them, working on classified things, particularly in chemistry, whom we knew about. We didn't know a lot about what was going on, other than that.

COHEN: You were all quite young then.

ACOSTA: We were, sure; seventeen, eighteen-year-old kids. We were not used to getting up early, and many professors complained that their students were falling asleep at eight o'clock.

COHEN: But I would guess that you were all used to working hard.

ACOSTA: Yes, we were. We all worked hard. And many of us thought, to begin with, that this was some sort of temporary duty and we would be sent off subsequently to boot camp. But that didn't happen. And it gradually dawned on us that if we worked hard, we could actually get BS degrees before we left here. I came in '43, as a sophomore. My class graduated in '45 with BS degrees, going full-time. We had three semesters a year with a week off between them.

Money was still hard for my family. My father was at sea then. My mother was working at Douglas [Aircraft] in Long Beach. And on my weekends off, I would go down and do long-shoring in the harbor for extra money. Loading ammunition and things like that.

COHEN: But you did have your weekends?

ACOSTA: We did have weekends. We had to apply for passes, but that was easily done.

COHEN: Did you get some subsistence here, aside from room and board?

ACOSTA: Yes we did. I was astonished. We were getting all this board and room and we got $50 a month, which was an enormous amount of money, because most of our needs here were already taken care of. So the extras were if we wanted to go to a movie or something like that. You didn't need to buy clothes, because that was all provided. We had to wash our own clothes and keep ourselves clean, the way the navy expects.

COHEN: You wore a uniform?

ACOSTA: We wore a uniform at all times. It was actually not bad discipline for a young man.

COHEN: I see. How much did you mix with the regular students?

ACOSTA: We didn't. There were too few civilian students to make a difference, so it was basically a navy contingent. The students we wanted to mix with, of course, were girls from other campuses, such as Occidental and Scripps. That condition remained until Caltech started admitting women—not all that long ago [1970]. The Nazarene College was in Pasadena. Those kinds of contacts were highly valued.

COHEN: It sounds like a good way to spend the war.

ACOSTA: Well, it was, yes. We referred to it with delight as fighting the Battle of Pasadena. We were very fortunate.

COHEN: And then when you got your bachelor's degree in '45, it was a Caltech degree.

ACOSTA: They weren't too embarrassed by us. It was a genuine Caltech degree. In my case, I went on to learn how to run steam turbine engines for boats, in the Newport, Rhode Island, steam school, a special school where you learn how to be an officer in charge of engine rooms.

COHEN: This was after you got your degree?

ACOSTA: No, I'm sorry, I spoke too soon. After we got our degrees, then we went to midshipman's school.

COHEN: You still had obligations to be in the navy?

ACOSTA: We were still in the navy, in active service. So I went to midshipman's school. The number-one person in my midshipman's class was Ruben Mettler [Caltech Board of Trustees, 1968-2006, d. 2006].

COHEN: Is that right?

ACOSTA: Yes, at Notre Dame. Notre Dame was a midshipman training school. I'd never been out of Southern California, so that was quite a change. We met with students from many other

schools.

Generally, the Caltech students did very well in midshipman's school, because even though the training wasn't as good then as it is now, we were still pretty good for the times. So midshipman's school was really kind of fun. And subsequent to that, I went to the steam school.

COHEN: How long were you at Notre Dame?

ACOSTA: A typical period then was three months. The steam school was three months, and then I reported to duty in Long Beach to go on what was called an amphibious transport craft. The war was over by this time. During midshipman's school, on VJ Day, we were at sea in Lake Michigan on a training cruise. There's a naval base in downtown Chicago. So I guess we were lucky to be at sea, because when we came back to Chicago, the city was literally this deep [points to table height] with paper and trash of all possible descriptions. It was a real wild party, so it was probably better for us to have missed it.

COHEN: So here you were. You had your degree.

ACOSTA: Yes, and we were still in the navy. I reported for service as an engineering officer on board this attack transport craft. We were assigned to go to Bikini Island, and that was kind of interesting for me. This was the Joint Army-Navy Task Force One. It was the first joint army-navy exercise in which they were to do these two experiments, to have two atom-bomb blasts.

COHEN: Did you know anything about the atom-bomb program?

ACOSTA: Only what I read in the paper. There were no rumors around campus that I remember.

COHEN: So even though things were going great out here in Pasadena, you had no awareness of it?

ACOSTA: I didn't, no. That was quite fascinating. But even then, when Hiroshima and Nagasaki occurred, it was certainly a real debatable thing, even amongst us then.

COHEN: Let me backtrack a little bit, because this reminds me of something. You were in this area in the forties, when they took all the Japanese off to Manzanar?

ACOSTA: Right, and there were many I knew. I think all of us then thought that was a terrible miscarriage of justice. We saw no excuse for it whatsoever. In our area, both my wife, who lived here in Eagle Rock and went to school there, and myself in Long Beach, saw all these people being taken away and practically dispossessed of their belongings.

Here at Caltech, there was a seminar by a local general who was in charge of military security for this area. He gave a talk to us explaining why this was the right thing to do. There were many hostile questions from this group of navy students. It was very poorly justified, because everyone knew that the population of Hawaii was thirty-percent Japanese and they were not touched at all. It was a complete miscarriage of justice. We didn't have anything to be proud about.

We lost a lot of bright people, some of whom I met later in graduate school. Some of them were able to move to the Midwest where they were not incarcerated in concentration camps. Have you driven out by where Manzanar was?

COHEN: Sure. It's on the way to the Owens Valley Radio Observatory.

ACOSTA: Yes. Pretty sad.

COHEN: And I remember, in Cleveland, some of the Japanese people coming.

ACOSTA: And living their normal lives.

COHEN: Anyway, the bomb just reminded me of that.

ACOSTA: Oh, the bomb was terribly controversial. And you know, that controversy grew. It didn't really subside.

COHEN: So you were actually in the Bikini area?

ACOSTA: Yes, I went to Bikini. Our boat was to service that whole operation. Joint Army-Navy Task Force One. Bikini Atoll. Someplace I have a little memento of that, and I have some maps of Bikini Atoll. I was transferred to a special small boat that was to do the radiological sampling after the first blast went off.

COHEN: Was there any sense of danger, in being so close?

ACOSTA: No. We were as naive as rabbits. You know, we were told about radiological dangers, but we didn't really understand very much about it. And by this time, there was public knowledge of what the blast was about and so on.

Anyway, our boats went fifteen miles off, and we had to look away and we had glasses and all that stuff. Then an hour later we went back to the atoll, and we off-loaded into the small boats. We went up to where the ships were anchored under the blast and collected water samples. The destruction of those ships was really quite awesome.

COHEN: And you didn't wear any special clothing of any kind? Nothing?

ACOSTA: No. These were small boats. I was the skipper. I had two crew, and then we had two people who were radiological physicists and they were in charge of directing where we went. We wanted to go by this burning ship, an aircraft carrier, so they requested permission to go over there. But we weren't allowed to go there, because it was too radioactively hot. We were told what radioactive exposures we were allowed to get. The people in charge were fully aware of the hazards.

I think Ruben Mettler was assigned to the general staff of that operation. And I think the man in charge eventually became dean of medicine at UCLA, Stafford Warren.

It was terribly interesting, you know. It was interesting to see all the different Japanese and German ships. And it was fascinating to see what different kinds of destruction the blast caused to them.

COHEN: You mean they just brought in different kinds of boats just to see?

ACOSTA: Yes, a full range of boats of different types. One of our aircraft carriers was there, and

there were two German light cruisers. Beautiful craft, they were. Just the sheer perversity of the kinds of damage these boats suffered. For some reason, steel poles were bent over in half and yet other things that looked vulnerable were untouched. Blast damage was really quite unknown.

The atoll itself was beautiful.

The armed forces were decreasing after the war, as you know. At that time, there was a prescription by which, in terms of type of service and length of service, you could be discharged. And so by 1946, for various reasons, I had met that magic number and could be discharged. So I did not stay for the second blast, which was the underwater blast, which ruined the island.

We all went home on what was then called the magic carpet. Morale in the navy was declining, because it was downsizing and many wanted to stay and be career officers.

COHEN: What was your rank at this time?

ACOSTA: I was an ensign and an engineering officer. The idea of being in the navy and away from family and normal civilization didn't really appeal to me, although it's fun operating ships. Boats are fun. The technical aspect of being in the navy was always appealing, but I didn't want to live half my life at sea. So I took the chance to get out and came here and was separated from the service in September 1946.

COHEN: So you spent not much more than a year on active duty.

ACOSTA: That's right, just about a year of active duty.

Wondering what to do, I came to what was then called the Caltech Placement Service, now called the Career Development Center.

COHEN: I see. So you came back to Caltech.

ACOSTA: To find out where jobs were, like many graduates.

COHEN: I see, not thinking school.

ACOSTA: Not thinking school, no, not at that time. And it turned out that there was a job opportunity here on the campus, in what was called the Hydraulic Machinery Laboratory. This is the laboratory that was built by Robert T. Knapp [professor of hydraulics, d. 1957], starting in approximately 1935, the purpose of which was to provide a uniform, even-handed testing facility for the new pumps for the Metropolitan Water District.

Large engineering projects have always been of great interest to me, and I had always liked the subject of turbo machinery, as Frank Marble [Richard L. and Dorothy M. Hayman Professor of Mechanical Engineering and professor of jet propulsion, emeritus] did, but from a somewhat different perspective. Frank was interested in air propulsion. But as an undergraduate student, I had always been interested in large power pumps and turbines.

There was a testing program in 1946, about to be concluded, for developing the pumps for the Grand Coulee Irrigation District, in the state of Washington. At that time these were the largest pumps of that type in the world, and, as events proved, they were of unprecedentedly high efficiency. High efficiencies are of interest to engineers and users, and those machines were over ninety-two-percent efficient, as measured in the laboratory. Levels of that sort of efficiency for rotating machines are not exceeded even today. So that was a very interesting project for a beginning engineer. A local company in Los Angeles, the Byron Jackson Company, was the successful bidder, and models of these pumps were being tested in the Hydraulic Machinery Laboratory, which is now the site of the Aeronautics Library in the Guggenheim building, so that seemed real interesting to me. There was a classmate of mine, Stan Clark, who returned from his V-12 service and two others at work already on the project.

COHEN: He had been at Caltech also?

ACOSTA: Yes, right. He got out early, before me, but we were classmates. Stan was the son of a municipal justice for Los Angeles. So we had fun starting to use our engineering skills in the testing of these pumps.

COHEN: Did this have anything to do with the academic program? Were there undergraduate students involved with it?

ACOSTA: No, this was strictly an engineering project.

COHEN: So Caltech was doing this on contract from someone?

ACOSTA: Essentially, yes. There were a number of projects like that around the campus, in the same sense that the infrared telescope and LIGO [Laser Interferometer Gravitational-Wave Observatory] are projects. They do involve graduate students, but the main thing is that they involve professional people to manage and do the technical work. Graduate students are really incidental to these large-scale projects.

It's always been a controversial issue, having large intellectual enterprises separate from the educational function on the campus. There's no campus that works well when that happens, and that's why it was always good that JPL [Jet Propulsion Laboratory] was remote from our academic campus.

Nonetheless this was a small-scale project by modern standards, although it provided opportunity for research and so on. At this time, we were all hired as engineers—not to go to graduate school, not to do research, but to carry out this testing and development work. But it was quite enjoyable work; it was current engineering of a high order, and it was a very useful thing to do. That lasted for perhaps a year, and then by that time I'd gotten interested in going to school again.

COHEN: Were you living in Long Beach at this time, or had you moved to Pasadena?

ACOSTA: No, I got a room here in Pasadena and pedaled to work. I started going to graduate school, at first part-time and then full-time.

COHEN: Was this in engineering or mechanical engineering?

ACOSTA: I stayed in mechanical engineering. I got a master's degree that way.

Let me explain a little bit about the Hydraulic Machinery Laboratory. It was started by Knapp, who was a very dynamic person. You really ought to have his collected works here. I'd be pleased to give you my copy, if you don't. He was a very hard-driving man, quite abrasive, very self-directed. I think the only advice he listened to was from [Theodore] von Kármán

[director of the Guggenheim Aeronautical Laboratory at the California Institute of Technology (GALCIT), 1930-1949, d. 1963], who was a very powerful figure, as you know.

In building the Hydraulic Machinery Laboratory and other testing projects like this, there were relatively few academic pursuits. Very few academic degrees came out of that process, for which he was criticized, as I learned later, by a number of people. There were some degrees early on, not tied in directly with the Hydraulic Machinery Laboratory. Richard Folsom got his PhD here in 1932. Folsom went to Berkeley, where he became a professor, and he eventually became president of Rensselaer Polytechnic Institute. And there were a couple of others. George Wislicenus graduated slightly later, in ’37 or thereabouts and his area of interest was primarily in pumps also. I think his was probably the second PhD in this group.

COHEN: Now, all this work was for the Water District?

ACOSTA: Primarily motivated by the Water District, yes. It was quite a novel laboratory for its time.

COHEN: The money came from the Water District?

ACOSTA: The money came from the Water District, yes. I think all of it came from the Water District, but the details of that are not quite clear to me. Vito Vanoni [professor of hydraulics, emeritus, d. 1999] may know more about that. Knapp had developed quite a team, but they were really all professionals. Graduate study was not the primary purpose of the lab at that time, the way I perceived it. It did a lot of good work, though.

By 1938, it was pretty clear what was happening in the world, and so Knapp began to modify the direction of his pumping work to look at issues that had to do with underwater problems for the navy—in particular, the ballistics of underwater torpedoes and propulsion devices and related issues. I don’t know exactly when this started, but I think it must have been in 1941 or ’42 when he converted the pump-testing feature of the lab into a water tunnel for testing torpedo models.

One feature of the high-velocity flow of anything in water near the ocean surface is that it boils, because of the reduction of pressure, and forms pockets of water vapor, or cavitation,

which changes in a major way everything in the flow about these bodies. The process of cavitation is an interesting phenomenon to this day, both in technical and physical terms, and even in some aspects of physical chemistry. That kind of phase change, complicated with mass transfer from dissolved species, is a complex issue still. It's so complex there's no simple answer, and no simple mathematical modeling is even yet possible to really solve all the technical issues of interest. So that became Knapp's major thrust for the remainder of his career.

COHEN: Did he have much to do with the aeronautics people?

ACOSTA: No, but you touch upon a very interesting area. Let me phrase this as graciously as I can. The answer is no. They did not have much to do with each other. It would be fair to say that the aeronautical people did not think much of what Knapp was doing.

At the same time, during the war, Fred [Frederick C.] Lindvall [chairman of the engineering division, 1945-1969, d. 1989] headed up a project on torpedo development for the navy in Eaton Canyon. And to a certain extent, what Knapp was doing on the campus and what they were doing in Eaton Canyon, and for the subsequent development of the Morris Dam torpedo test facility, was competing for the same money. This led to some questions of what Knapp's lab, now called the Hydrodynamics Laboratory, was doing, particularly after the war.

COHEN: They were working on the same projects then? In some sense, the same idea?

ACOSTA: The same idea, yes; namely, the stability of aircraft torpedoes in water. So I do not think the feelings were all that generous between the aeronautics group and the hydrodynamics group. They occupied the same building; in fact, I really think it was more than that. There were really rather bad feelings between them, which I think dissipated only after the Hydrodynamics Laboratory became managed by the aeronautics department.

COHEN: Is that because the major players are gone?

ACOSTA: Well, yes. I don't think Lindvall thought that Knapp should be doing what he was doing, and in particular doing it on the campus, when at that time this was a classified project.

COHEN: This was Knapp's project?

ACOSTA: Yes, this torpedo work and some related things. I think this work tended to be classified until maybe the early fifties. And there was other classified work that had gone on during the war and after the war, in chemistry and other places, too. And you know, classified work doesn't really belong on a campus.

COHEN: Was Lindvall doing any classified work?

ACOSTA: Well, after the war, Lindvall came to head up what is now the Engineering and Applied Science Division. He wasn't keen on classified work, and by that time he'd left his work on the Morris Dam or Eaton Canyon torpedo project.

And so, when Lindvall came here, his interests were a hundred-percent academic. As I mentioned, he did not feel comfortable with the Hydro Lab run by Knapp, doing the things they were doing. There was this dichotomy between aeronautics and the hydro group. We young people didn't really know much about this; we were kind of unaware of campus politics. Most of us thought, rather naively, that at a wonderful place like Caltech there shouldn't be any politics. [Laughter] Which shows what we knew about human nature.

ALLAN J. ACOSTA

SESSION 2

April 27, 1994

Begin Tape 2, Side 1

ACOSTA: Just after my separation from the navy, I came to the Placement Center here, as I believe it was called then. There was an opening in the Hydraulic Machinery Laboratory, which was run by Professor Robert Knapp. At that time they were carrying out the execution of the acceptance tests for the Grand Coulee irrigation pumps being built by the Byron Jackson Company; the chief engineer for the Byron Jackson Company was a very impressive man. Working very closely with this group was also Professor Aladar Hollander, who was a retired former chief engineer of the Byron Jackson Company. At that time, he had become an associate professor of mechanical engineering, with an interest in teaching hydraulic machinery and machine design. He worked very closely with Robert Knapp, who had brought him to the institute from the Byron Jackson Company. Aladar Hollander was to prove very important to me. He was a wealth of information about his field, which I grew to enjoy very much. He had been a student with von Kármán at the Budapest University, in Hungary, where they knew each other.

COHEN: Hollander is Hungarian also?

ACOSTA: Yes, he is. And his father was a physician. Hollander for some reason was turned not toward science but toward engineering. He knew the famous engineers in Hungary at the time. Hollander went to school in Switzerland at the Swiss Federal Institute of Technology, and emigrated to the United States to work on submarines during World War I.

COHEN: So he came very early.

ACOSTA: Yes, very early, but he never lost his thick Hungarian accent. That seems to be an affliction for Hungarians when they learn English—they all have thick accents. It does give them a special character.

He was a marvelous man. He was one of the team later that assembled von Kármán's collected works, which we all bought. Hollander was an enormous well of information about rotating machinery of all types. He was a very wonderful man to work with; he had a good feeling for design and a wonderful spirit.

Also at the same time, Dino Morelli [professor of engineering design, d. 1972] worked in the Hydro Lab. Dino had emigrated from Australia, and he had designed much of the apparatus in the new Hydrodynamics Laboratory. But he was the leader in building a new pump laboratory that I helped to design, together with William Osborne, who was on leave from a pump company, Ingersoll Rand. Morelli subsequently had a very colorful career as a teacher of design in the mechanical engineering department at Caltech, until his death.

But to conclude here, after the acceptance tests, which were over roughly in 1947, it seemed like a good time then to think about doing more advanced work, since that was of great interest to me. And everything around said that more education was the right thing to do. So I did go to school part-time to get a master's degree, working in this new lab that Morelli and Osborne were working on.

At that time, all the returning servicemen were at Caltech, and the class structure was very different. There were many sections of classes. There were many sections of beginning dynamics and engineering courses and mathematics courses. The whole mood was one of highly focused, sincere work on the part of these mature men, who were now taking up their interrupted studies. It was a good time.

One of these men was Blaine Parkin, who had returned to do his graduate work. Blaine Parkin became very well known in his own study of cavitation. He subsequently became director of the Garfield Thomas Laboratory at Penn State, which is one of the largest laboratories of its kind in the world, from which position he has recently retired.

COHEN: Now, Morelli was your professor at the time?

ACOSTA: Morelli was the supervisor of the new small pump laboratory project. He became a professor and then he left the Hydrodynamics Laboratory in about 1949. Blaine Parkin and I are more or less contemporary. Blaine received his degree a year ahead of me, 1952. By about this time, 1948-'49, Milton Plesset arrived as a professor of applied mechanics. He carried enormous

technical authority in his field. He had left the field of physics—in particular, quantum mechanics, in which he had made notable, independent contributions—to take up the study of hydrodynamics. He immediately set up a real scientific approach to the subject of hydrodynamics and cavitation and started a program of graduate research with students that was most exceptional. A criticism of the Hydrodynamics Laboratory before was that it was more engineering-test-and development-oriented than academic- and research-oriented. Plesset supplied that real physicist's understanding of this branch of fluid engineering.

He was a very popular fellow, and we as students were all very much attracted and somewhat awestruck by him. He was very impressive and rather overwhelming, so we were somewhat timid, too. Like many well-known people, he did not suffer our foolish questions very well, and he was a master of one-liners. Some of them were so apt that they could also be cutting. We expected that, as students; his colleagues didn't particularly care for that gift of his, though. In fact, it led to a sort of falling out between him and Knapp.

By this time, let's see, in 1949 after the master's degree, I went back to school on a full-time basis.

COHEN: Was the master's degree not a full-time thing?

ACOSTA: I did that part time, working part time in the Hydraulic Machinery Laboratory and taking courses part time. That was wonderful for me, but since then, the institute doesn't welcome part-time students. I think that's a good plan, frankly. Nevertheless, it served me well at the time, because we were all trying to establish ourselves, get back to a steady state after the end of the war. One source of financial help then was the GI Bill, which was a wonderful support for returning servicemen, and I had basically used all of that up after a year. So Aladar Hollander got me a fellowship, supported by the Byron Jackson Company, for my last year of study.

By this time, I had taken courses from Plesset, Arthur Erdélyi [professor of mathematics 1949-1964, d. 1977], Homer Joe Stewart [professor of aeronautics, 1942-1980]. All these people were remarkable teachers. Arthur Erdélyi, another Hungarian, came to head up the Bateman project in mathematics. There's the Bateman series of books he edited. He was a magnificent teacher. He returned to Edinburgh subsequently, where he ended his career.

COHEN: Caltech was endowed with several Hungarians at that time.

ACOSTA: Yes, it surely was.

Homer Joe Stewart was the person I knew best in aeronautics. I did not know Millikan very well.

COHEN: That's Clark Millikan?

ACOSTA: That was Clark Millikan [director of GALCIT from 1949 until his death in 1966]. The Hydraulic Machinery Laboratory was in the aeronautics building. There was a lot of close association between the two groups. Von Kármán had a supervisory position over Knapp. I did not know Kármán myself, personally. This was in the early days of the testing of the pumps for the Metropolitan Water District. He was the person everybody went to for advice. But by that time, the late forties, von Kármán had left for AGARD [Advisory Group for Aerospace Research and Development] and Aerojet and many other activities.

But subsequently, between the aeronautics group and the hydrodynamics group, there was not any real feeling of cooperation. There was some feeling of actual competition, and I, as a student, then later as a staff member, was put in a difficult position, because there was just a real separation and a feeling of conflict, as previously mentioned.

COHEN: Now, was this personality or just a difference in where things were going?

ACOSTA: I think it was a combination of many things, stemming from the war and perhaps the fact that the Hydro Lab had not really engaged in as many academic research activities as I think many people thought they should have. And of course, Plesset was instrumental in changing that, but that brought him into conflict with Knapp.

Milton decided to leave the Hydro Lab in 1952, I think. He moved to the Thomas building [Franklin Thomas Laboratory of Engineering], where he became more active in applied mechanics, and subsequently he formed a new option, engineering science. Ted [Theodore Y.] Wu [professor of engineering science, emeritus] and [Hans] Liepmann [Theodore von Kármán Professor of Aeronautics, emeritus] also participated in that option. Engineering science, taught

by Plesset, Wu, and others, was really a classical physics point of view of fluid mechanics, solid mechanics, electricity, and magnetism. It was a very fine program for engineering PhD students.

By that time, I had my degree, Ted Wu had his, Albert Ellis had his. And then the three of us tried to work together to emphasize graduate research and take what we thought would be more of an academic approach to running the Hydro Lab. Of course, our main customer was the navy, because the navy had built those facilities and in fact owns them today. So we made a sincere effort to do that and were, I think, reasonably successful.

But we were all young assistant professors. We had no strong leaders, and as it happened, by this time, 1954, we were all on the staff of the Engineering and Applied Science Division: myself in mechanical engineering [mechanical engineering was a subject then, not an option—ed.] and Albert Ellis and Ted Wu in applied mechanics, which was a recently formed option within the division. Subsequently, Ellis went to UC San Diego and Ted joined Plesset in this new engineering science option. And it just didn't seem to me to be a viable situation to run the Hydro Lab myself. So I asked the chairman, Fred Lindvall, to have aeronautics take over the physical management of all those facilities. And under Ernie [Ernest E.] Sechler [professor of aeronautics, d. 1979], they did do that. All the hydrodynamics remained in the laboratory there, and subsequent activities were largely carried out by the aeronautics department, where it remains today. We felt good about that, because then there was an integrated series of fluid-flow facilities, encompassing low-speed aerodynamics, hydrodynamics, as well as the supersonic facilities being run by Lester Lees [professor of environmental engineering and aeronautics, d.1986]. So it's a very impressive, unique collection of research tools in fluid mechanics.

COHEN: Was Lester Lees brought in to do this?

ACOSTA: No, he was not. He was a teacher here during the war. He was a very dynamic teacher and researcher. I remember him as an instructor in calculus. And then he went back to MIT after the war, where he did some very basic work with C. C. Lin. And he returned in the late fifties to run the supersonic-flow facilities in the aeronautics department.

COHEN: Didn't he go into environmental things?

ACOSTA: Yes, subsequently he did. In the seventies, he became very concerned with energy matters. You may remember the freeze on gasoline and then all the worries over energy matters and their relationship with the environment. He was very actively involved in the Environmental Quality Lab when it first got started, and he taught beginning courses in energy for the freshmen. In the meantime, supersonic research had been very heavily worked over, so he moved more and more into this environmental area. He was a very impressive man. A wonderful teacher.

COHEN: So he was in charge of...

ACOSTA: Supersonic wind tunnels. Subsequently I think Toshi Kubota [professor of aeronautics, emeritus, d. 1999], who was one of his students, stayed to carry out a great deal of research in the field. Earlier on, in the fifties and sixties, JPL had very famous supersonic wind tunnels. They do not now, but at that time high-speed aerodynamics was associated with missiles and things of that sort, which was a very useful thing for the army, which at that time ran JPL. But under NASA those facilities have been disbanded. Supersonic research *per se* became a somewhat worked-out field. And so Toshi Kubota did less and less in that field until his retirement.

I still had some projects using the high-speed water tunnel. The old Hydraulic Machinery Laboratory was dismembered in 1961. It had served its function. We hadn't done any real research in there for some time. In its place, they put new laboratories, and the aeronautics library was moved. And it's nice. One thing about equipment, once it serves its function, it ought to go. So we didn't shed any tears about that, even though we'd spent hundreds of hours working in that facility.

COHEN: Now, let me get this straight. All these facilities are over there in the aeronautical engineering building, but they're being run by people over in Thomas?

ACOSTA: Oh, no. Wu and Ellis and I and Plesset were all housed in the Kármán lab [Guggenheim Aeronautical Laboratory] in those times. Once we physically left that space, everyone was turned over to aeronautics, and we moved to Thomas.

COHEN: Were you ever part of the aeronautics group?

ACOSTA: No. The hydrodynamic group and the hydraulic machinery group were always administered separately from the aeronautics academic staff, as well as from the aeronautics experimental facilities.

COHEN: So you did infer that there was a certain amount of competition and maybe not always good feelings between the two groups?

ACOSTA: No doubt about that.

COHEN: Was that a personality thing?

ACOSTA: Partly rooted in history, surely. Lindvall ran the Eaton Canyon project during World War II, which was developing aircraft torpedoes. And Knapp, from the same sources, built up a laboratory, and the new water tunnels that are there now, to do somewhat the same thing—to make model experiments on aircraft torpedoes to find out why they didn't work right. During the war it was all a classified proposition, but after the war you just can't do classified work in an academic environment properly, although there were classified things going on in that facility through 1953. My understanding is that Professor Lindvall, when he came back to head up the engineering division, did not think well of this kind of nonacademic activity at Caltech specifically, but certainly in academia generally. So that was one strike against it. Secondly, during the war—here again I'm depending on the history of my forebears—there really wasn't any real cooperation except when Kármán was here and had the forceful personality to...

COHEN: Make everyone behave and do what they should do.

ACOSTA: That's right. Once he left, there didn't seem to be any interaction between the two groups at all. There was really some antipathy, and no one really wanted that.

COHEN: Well, of course not. So when graduate students would come, would they come to work for a specific person?

ACOSTA: Usually they would, yes. People like Plesset liked graduate students. He had many graduate students. Many of them became very well known subsequently. As soon as he arrived at the Hydro Lab, he attracted graduate students. And so the level of the work, from my point of view, really increased remarkably well.

COHEN: He was on the ball.

ACOSTA: He was. And he had a lot of chutzpah. I think that somewhat alarmed the administration, because Fred Lindvall saw Milton building an empire there. Now we were, you know, much younger and inexperienced; we didn't see that empire-building. Nonetheless, all those factors I think made Milton decide to run his own show, together with Ted Wu in applied mechanics—to leave off administration of facilities. So that left Ted and me and Albert there.

COHEN: So then it's 1960, and you're a professor.

ACOSTA: Yes. Lindvall asked me to go on the staff in '54 to help teach in mechanical engineering. I took a pay cut to do that, as we all did. We never worked at Caltech to make money. We didn't even think about things like that. It was just unthinkable. It isn't that way now. And we didn't make much money, either. At the end of the month, there was nothing left. I'm sure you remember those times. We enjoyed our work.

COHEN: So by the early sixties, when you cut off that facility, you must have already been tenured. Is that correct?

ACOSTA: Yes, I've forgotten when exactly. [Prof. Acosta received tenure in 1958—ed.] Things were rather informal then. I know I've talked about this with Tom [Thomas K.] Caughey [professor of applied mechanics and mechanical engineering, d. 2005]; most of us never knew when we got tenure. The idea of getting tenure and so on was not so much a watershed. We didn't really think about it.

COHEN: You mean you did your job, and one day you realized you were permanent.

ACOSTA: Yes, that's more or less what happened. And of course the institute was building then. It needed staff. Of course, funds weren't very big then. Neither were our salaries. Neither was the overhead. My first recollection of the overhead rate was twenty-two percent. What is it now? It's fifty-four-and-a-half percent.

So at any rate, Albert Ellis moved on to San Diego. Ted Wu took a sabbatical to Germany, and so I ran the show by myself for a year.

COHEN: This was in the early sixties, right?

ACOSTA: This was the very early sixties. And so I had the chance to take my one long sabbatical. In '62, I was teaching courses in fluid flow and heat transfer with Rolf Sabersky [professor of mechanical engineering, emeritus] in mechanical engineering. We had not yet destroyed the Hydraulic Machinery Laboratory, but in the late forties I had made, with Morelli, a different laboratory, and I was using that for some of my work.

COHEN: And where was that located?

ACOSTA: That was located in the old Hydraulic Machinery Laboratory—the physical space. I built myself a number of facilities that Duncan Rannie [Goddard Professor of Jet Propulsion, d. 1988] used on some of his axial flow compressor work. And I had to use it on some of my work on cavitation in axial flow machines. I've forgotten exactly when that facility was destroyed. I think it was something like '65 when the whole Hydraulic Machinery Laboratory was taken out.

COHEN: But meanwhile, in 1962, you went off on sabbatical.

ACOSTA: I went on sabbatical to Imperial College in London to study meteorology. And that was a wonderful experience. It was really wonderful to do the same subject but from a completely different aspect, which meteorology is. And England was wonderful. I really enjoyed it. English fluid mechanics is always somewhat different. Highly idiosyncratic, but you studied German texts as well as English texts in that field. The two were different, and both famous and enjoyable. It was a wonderful experience to spend a year doing that.

COHEN: You lived in London?

ACOSTA: Yes, we did. Who wrote *The Importance of Being Ernest?* He had a famous trial, and he had to leave England. [Oscar Wilde—ed.] We lived in his mother's house.

COHEN: You must have had family by this time.

ACOSTA: We had a family, yes. We had two children, and we lived in a maisonette in Chelsea. The Embankment was just a block away, and famous people lived right, left, and center, all around us in Chelsea. I walked from there to the university every day. That was really wonderful.

COHEN: So you were there for a year?

ACOSTA: Yes. I came back thinking I would do some geophysical fluid mechanics, but I never did, because of the demands of what we had to do in the Hydro Lab and my other things that were there. So I stayed in what I would say is traditional mechanical engineering, fluid mechanics, ever since.

COHEN: So then in the middle sixties, you came back. And did you then proceed to build a new facility?

ACOSTA: Well, the aeronautics library at Caltech went in where the Hydraulic Machinery Laboratory was housed. That would have been the basement and first floor of what is now Kármán [Kármán Laboratory of Fluid Mechanics and Jet Propulsion] and Guggenheim. Then pretty shortly after that, I moved back to Thomas, although some of our students were still housed in Kármán. For our research facilities, I would rent space in the water tunnel. I used the water tunnel even though Ernie Sechler was administering it. That worked out just fine.

It was a relief not to have to be responsible for employees. It's one aspect of running an industrial development thing in an academic environment. You have the business aspects of running it and being responsible for people on contract money. And if that contract money goes away, as many of my groups and the groups here at Caltech have, why, there's real stress.

People who spend their lives under these conditions then have their jobs at risk. That's not a good operation.

COHEN: Well, some of those problems still exist.

ACOSTA: They still exist in various areas around the campus.

COHEN: What was the subdivision of your department called?

ACOSTA: Formally, I was in mechanical engineering. Mechanical engineering is a very broad field, and there are many specialities within it: Some are like applied physics and others are management. Our area, in fluid mechanics and heat transfer, is a highly technical area and approximates very much applied mathematics. Other parts are very experimentally oriented.

COHEN: Who was actually in your group?

ACOSTA: This particular group was small. It consisted of myself; Rolf Sabersky, whom I have known since 1945, when he was an instructor in mechanical engineering. Rolf and I had started on a textbook together, which we published in '63 [*Fluid Flow: A First Course in Fluid Mechanics* (New York: Macmillan)]. It is still published.

COHEN: It is. I have a copy and looked at it!

ACOSTA: Oh, well, thank you. Let's see, there was Rolf and myself. Now, the other sort of schism in mechanical engineering was the jet propulsion group. The jet propulsion group was formed in the late forties, when H. S. Tsien returned from MIT to head it up. The other members of that were Duncan Rannie, officially a professor of mechanical engineering; Frank Marble, who, as you know, had two labels, professor of mechanical engineering and of jet propulsion. And then in the late fifties Ed [Edward E.] Zukoski from JPL came and joined that group. Then after him, Fred [E. C.] Culick, who now is a professor of jet propulsion and mechanical engineering also.

Duncan Rannie was one of my teachers, and he was Rolf's supervisor. He was a very

dear man, and I listened faithfully to everything he said. He was a wonderful man on a one-on-one basis. Kind of a dour Scot. Very critical. So critical that Sabersky and I would never publish anything unless we thought it was perfect. So we wound up not publishing very much when we were young.

COHEN: Well, that's probably OK, too.

ACOSTA: Yes, I wish more people had done that. So he was a very important influence on both Rolf and me. But nonetheless, those people, Marble and Duncan and Zukoski, really were part of an extended mechanical engineering group. In fact, in some universities, there is no separate aeronautics department; it's often called the mechanical and aerospace division. Aeronautics is, you know, a name for a very large umbrella, covering a sphere of activities, of which one part is applied mechanics, which means the application of mathematics and the study of vibrations in solids. So there is a group in aeronautics who does applied mechanics, and there's a group in aeronautics who does fluid mechanics. It's a very smooth continuum, where we all basically work in the same field. But it was because the Guggenheim Aeronautical Laboratory was formed as an institute separate from the undergraduate teaching that it had its unique hierarchical character. It has a director; no other equivalent academic enterprise here has a director. I suppose in that sense it's more like the Seismology Lab. The Seismo Lab is a research facility, but it's also a technical enterprise.

COHEN: It serves industry.

ACOSTA: It serves industry, right. So that's why at Caltech these organizational relations are different from other institutions. So the mechanical engineering group that I looked to for advice, and so on, was Sabersky and Duncan and Marble and Zukoski. We all overlapped in our area of activity. The thermal fluids group in Thomas was really quite small; in fact, it remained small until recent times.

COHEN: What were your efforts when you came back in the late sixties?

ACOSTA: Well, I had this lifelong love affair with turbo machinery, which was one of Duncan

Rannie's main interests, too. I was more interested, and I had worked in the Hydro Lab before with pumps. They were liquids that had their own unique problems, different from gas turbines, which were Duncan Rannie's and, at that time, Marble's interest—Marble less so in recent years, once experimental work in gas turbines was stopped here. I continued my interest in hydraulic machinery, and after the Hydro Lab was taken away, there were lots of paper things I could do. Little theory kinds of things. Starting in the early seventies, there were some very interesting technical problems that came up involving space propulsion, having to do with pumps. When a rocket, particularly a liquid-fueled rocket, is launched, it's possible to have this effect that became known as the pogo effect. You know what a pogo stick is; it bounces up and down. And that process can happen with a liquid-fueled rocket, because the liquid-fueled rocket is basically like a rubber balloon full of water. It's very squeegee. Any little disturbance from the propulsion end causes a jiggle, which gets amplified and leads to a sometimes violent oscillation. So much so that men could not fly in rockets without our understanding this and working on it. And it so happened that I got involved in that. I started in the early seventies working on this kind of problem and then built a small laboratory to study this particular effect, but this time in Thomas. And a few years later, Chris [Christopher E.] Brennen [Richard L. and Dorothy M. Hayman Professor of Mechanical Engineering] was brought here by Ted Wu as a postdoc from England to work on theoretical cavitation and then biofluidmechanics. Chris became interested in turbo machinery also, so he came to work with me. We have had a series of students come out of this laboratory for some twenty years. A small tabletop, practically. Graduate students operated it themselves. We don't have any research staff. We don't need it.

COHEN: You don't want any.

ACOSTA: We do it all ourselves. We really did some highly original work, which has subsequently been followed up in many other countries. So that was a lot of fun to do.

COHEN: Now, did you have grants to do this work?

ACOSTA: Yes. In fact, I got a grant, let's see, in 1974 from NASA, and that grant has been continuous up until last year. We do not have a grant from NASA now. But a continual

contractual relationship for twenty years is not too bad.

COHEN: That's good! So then Chris Brennen came here to work.

ACOSTA: Chris has become more and more interested in that, and he's really become completely involved in the field also. So we have a long continuity here of an area in a field that goes back to the early time, starting with Knapp and his work in the thirties.

COHEN: What are some of these unique things?

ACOSTA: Well, in the early days, most people wanted to make machines as efficient as possible. But most of the problems that machines get into are because they have a kind of behavior, like this pogo oscillation that I mentioned, the source of which is unclear. We became interested in trying to understand unusual phenomena that sometimes, if allowed to go unchecked, will result in destruction. So we were looking not at doing incremental improvements in efficiency, or design work, but trying to understand heretofore unknown phenomena crucial to a successful operation.

COHEN: What were some of the problems you were attacking then?

ACOSTA: When aeronautic propulsion came on the scene, it became possible to release energy in a small space at rates that were never before thought of. We express that term by saying the density of the power release is very high. We used to call them high-power density machines. And this trend has continued. Machines have become smaller, much faster. And the level of power release is incredible. For example, the pumps on the space shuttle have machinery that we've worked twenty years on. You can hold one in your hand, and they release 70,000 horsepower. You know what 100 horsepower on an automobile engine is. Something you can't lift.

COHEN: That's correct.

ACOSTA: So we're talking about an increase of many orders of magnitude and a whole new

spectrum of operating problems and phenomena that had never appeared before and had to be coped with. There are problems that people in applied mechanics work on, there are problems of materials and failures, there are new flow phenomena, there are new solid mechanic phenomena.

COHEN: So who came to you? Did anyone come to you from the outside to ask you to solve these problems?

ACOSTA: Yes, I don't know how. I met a person at NASA and I had a student, Jong Kim, who was working on doing some theoretical work on a problem in cavitation. And he [the NASA person] said, "Gee, that's interesting." And I knew about the pogo problem, I'd worked on that for the Gemini launch craft for industry. And he said, "Here, I've got $25,000, would you like to study that?" And I said, "Sure." So a year later, Jong Kim graduated; he's now at the Electric Power Research Institute, where he works on the flow problems of nuclear safety. A year later, my NASA contact called me up on a Thursday and asked, "Would you like to do some experimental work?" Well, I really do love experimental work and I said yes. He said, "Give me a proposal for $100,000 on Monday." So I did that, and we started, and a year later we had a facility. That's the way it started. And it's still going on. And Chris [Brennen] is very much interested in this whole field, so I feel there is a good strong sense of continuity.

COHEN: So this continued through the seventies.

ACOSTA: Yes, through the seventies and up to the early nineties.

COHEN: Apart from the lab, how involved were you in the teaching, the structure of your department, the engineering division?

ACOSTA: Well, unlike other divisions, in our division, you're required to teach every term. We all taught. Most of us in engineering also tried to do some consulting. First of all, it helps. Unless you are involved in things on the outside, your engineering skills become, well, irrelevant. You must be engaged.

COHEN: So it's really almost a must that people in engineering do some consulting.

ACOSTA: You bet. Otherwise, you become a paper teacher.

COHEN: That was really one of [Robert A.] Millikan's original ideas when he set up this place: to interact with the community.

ACOSTA: That's right. So I consult, on the average, one day a week, and I still do that for a variety of local industries. I've done a lot of design work myself. When you fly on Boeing airplanes, and other airplanes, there are little gadgets that I've designed that are whirling away. And that gives one a good feeling—that one's contributed technically to what we are doing. And in motivating students, it makes a difference whether you have no contact with reality or really know what it is from the bottom up. I've found that students always like to know about these things. I take them to see how things are made on the outside and bring them pieces of things that I have designed and worked on, so that they get some idea of how it's done.

COHEN: So the consulting world is really very much a part of the engineering division.

ACOSTA: Absolutely. It really has to be. I think most of the people who are really good in our division do that. Not just to make money but to keep current and keep up with it.

COHEN: Now, did you teach just engineering students, or did you teach for mathematics or physics?

ACOSTA: Well, I taught courses in fluid mechanics and heat transfer in my work here. And now and then in fluid mechanics a geologist would appear; they need to know something about that subject. But most of our courses are not service courses, in the sense that mathematics is something everyone has to know. Beyond Math 2, our division offers a third-year mathematics course, which I could have taught if I was interested in doing that.

COHEN: And that would be problems that you solve in engineering?

ACOSTA: Yes, except about half the students do come from the science side. Our junior-level course in mathematics, AMA 95, is taken by students from all over the campus, and it's a

thorough course in mathematical analysis. It puts our students, as seniors, ahead of many students at the master's level elsewhere. It means they don't get the wool pulled over their eyes in courses in which there are a lot of formal difficulties. It's a tough course.

ALLAN J. ACOSTA

SESSION 3

May 3, 1994

Begin Tape 3, Side 1

COHEN: Do you think perhaps you could go back a little bit and talk about the relationship between the aeronautics section and hydraulics, because that evidently was not always so smooth.

ACOSTA: No. In fact, the aeronautics department and GALCIT [now called the Graduate Aeronautical Laboratories, California Institute of Technology] is an interesting and unique part of Caltech life, because it occupies a central role in applied and theoretical fluid mechanics in the whole country, if not in fact all around the world. It began with the highest level of people. But it began and essentially remains a graduate research institution, having in some ways its own momentum and, in former years, access to money through doing research with its wind tunnels for outside companies. And it enjoys a uniform and well-deserved reputation in industry. It was very high-profile, particularly when von Kármán came. Clark Millikan himself was a luminous figure back in the late thirties and did many important things. But that sort of a graduate institute did not really participate in the undergraduate life that was found in the other conventional divisions. The electrical engineering group, when I was an undergraduate, was officially part of physics, not a part of engineering. So engineering has undergone—both on the undergraduate level and the graduate level, together with the aeronautics group—a real structural change over the years.

The hydraulics group, under Robert Knapp, took space in the Guggenheim Aeronautical building to construct the pump testing apparatus—the Hydraulic Machinery Laboratory, which was to be used to develop and measure and characterize the pumps for the Metropolitan Water District. And the scientific level of that effort—this is my interpretation, now—was not seen by others as being at the same level as what was going on in aeronautics at that same time.

COHEN: Was that because it was applied research rather than basic research?

ACOSTA: It was much more applied research, and I'm sure that was an essential feature of it. At the same time, Knapp devised entirely new means for making a parallel, accurate measurement of these things, so that one could really distinguish between this and that design and various manners of operation in which it worked. But there was certainly an uncomfortable relationship, so although you could walk through one door from one place to the other, there was an invisible barrier there.

COHEN: Was that a personality thing or just a difference of objective?

ACOSTA: Well, from my perspective as a junior engineer to begin with, it was largely that one group didn't really like the other. The level of academic activities in the hydraulics group did not nearly match that of the aeronautics group. And subsequently, as a graduate student, I took courses from the aeronautics people and they were wonderful. I enjoyed them immensely. Many of us who were students, particularly when Milton Plesset came on board, tried to work at the top level that you're expected to when you're at Caltech in any department.

COHEN: Now, Plesset was firmly in the applied mechanics?

ACOSTA: He was firmly in applied mechanics.

COHEN: He was not a part of the GALCIT group?

ACOSTA: No, he was not. And I admit that history was there. I think there are many people around who have long, institutional memories who are now retired, and what with new division chairmen who came along after Lindvall and real attempts at collegiality, I think the whole environment there is utterly changed.

COHEN: So people came in—

ACOSTA: And made an effort, I think, to be collegial. In that respect, I think many of us owe Roy Gould [Simon Ramo Professor of Engineering, emeritus] a vote of thanks for his gentlemanly and even-handed administration of everything in our division. He was a marvelous

breath of fresh air for many of us.

COHEN: When did he come?

ACOSTA: He was the chairman, I believe, before Paul Jennings [professor of civil engineering and applied mechanics]. [Roy W. Gould chaired the Division of Engineering and Applied Science from 1979 to 1985, immediately before Paul Jennings—ed.] And he was, I thought, very effective and really made it a much more pleasant and collegial environment than it had been before. He was not manipulative. Open-handed. Didn't try to play games.

COHEN: Who was head of GALCIT when he came in?

ACOSTA: When Gould came in, Hans Liepmann was. You see, there haven't been all that many directors [of GALCIT]. There was [Clark] Millikan for many years. Ernie Sechler was acting, then Hans Liepmann for many years, until Hans Hornung [Clarence L. Johnson Professor of Aeronautics, emeritus]. So each of those people carry with them a long history.

COHEN: It seems that's quite traditional here at Caltech. People come and stay.

ACOSTA: Yes, that's true. It's particularly true in GALCIT, because the present staff there — why, the last two appointments were Caltech PhDs, of course. [Anatol] Roshko [Theodore von Kármán Professor of Aeronautics, emeritus] and [Donald E.] Coles [professor of aeronautics, emeritus] as well as [Paul E.] Dimotakis [John K. Northrop Professor of Aeronautics and professor of applied physics] are also Caltech graduates.

COHEN: So this just evolved during your tenure, the last dozen years or so. It's been good cooperation between the two departments.

ACOSTA: Yes, I think so. It is still a graduate option, so they have their own thrust and their own momentum. But nonetheless, I think there is a really different situation now. There's a lot of cooperation with other groups, with applied physics and even mechanical engineering in the training of students and sharing research interests and interactions.

COHEN: So would you say that the engineering division is a much calmer, pleasanter place than it was in past years?

ACOSTA: Much, much. Well, at least the parts I know about. I can't answer for computer science or other areas.

COHEN: OK. Now, you wrote a textbook with Rolf [Sabersky].

ACOSTA: Yes. Rolf had written an earlier textbook, in thermodynamics [*Elements of Engineering Thermodynamics* (New York: McGraw-Hill, 1957)]. Going back to those times, the group in mechanical and civil and, partly, applied mechanics, together with those in EE [electrical engineering], were responsible for teaching the undergraduates. The people in aeronautics, until comparatively recently, did not have much of a role in undergraduate teaching, and back in the fifties and sixties there weren't many textbooks. There were some, of course, but these were changing times, and newer, higher, more scientific content was creeping into all kinds of activities, and engineering was surely not spared that. In fact, we tried to make it more scientific, and von Kármán was certainly an outstanding example of a person who started that. It all came from this German approach to applied mechanics and technical mechanics. So, yes, there was a great need for books, and since we were all giving lectures based on notes, from our own notes and from various sources we could put things together.

COHEN: So the books just didn't exist for teaching.

ACOSTA: That's right. [Donald E.] Hudson [professor of mechanical engineering and applied mechanics, emeritus, d. 1999] put together two books and then later [George W.] Housner [Carl F. Braun Professor of Engineering, emeritus] wrote another book. All these were at more or less the junior level and fulfilled needs that were not fulfilled in the American college press. Rolf similarly did an undergraduate textbook in applied thermodynamics, and then later we started on one based on our teaching undergraduate fluid mechanics. Fluid mechanics is a pretty large subject, and it's one that Caltech and our division is noted for. It has applications in all fields in engineering as well as science. And so it was and still continues to be a very popular

undergraduate course. It's one of the core courses. Rolf and I were both surely influenced by our exposure to the graduate-level courses that were taught in the aeronautics lab at the same time. And there are wonderful applications in civil engineering as well as mechanical engineering. Probably in the engineering world, there are more people who use that subject in mechanical engineering than in any other sort of well-defined division. It is and has been one of the strengths of Caltech. And despite the need to start new intellectual enterprises in a faculty that is more or less limited to a constant size, Caltech's expertise in fluid mechanics, with recent appointments in aeronautics as well as mechanical engineering, are still support for fluid mechanics, which is something that demands and requires continual research.

COHEN: Very good. So you deal with undergraduate students. Do many of them stay on and do graduate work here, or do they go to other schools?

ACOSTA: Yes. Well, one of my most pleasant and famous of our undergraduate advisees who took all these courses is Tony [Anthony] Leonard [Theodore von Kármán Professor of Aeronautics, emeritus] who eventually has studied in a number of fields, including neutron-transport theory and now is a valued member of our division, working continually in fluid mechanics from a numerical point of view. Many students stayed on, yes. Paul Dimotakis was in my freshman advisory group. Paul stayed on, also in fluid mechanics.

COHEN: Is he now in charge of this lab?

ACOSTA: One of Paul's interests is in the use of the old Hydrodynamics Lab. He uses the two water-tunnel facilities there. And I believe he's the main person there who has an interest in those at the present time.

COHEN: You taught undergraduate courses?

ACOSTA: Yes, in fluid mechanics and in heat transfer, for many years; also the graduate heat-transfer course. Heat transfer and fluid mechanics are intimately connected subjects. It is a major area, mechanical engineering as well as chemical. In fact, our interests overlap in chemical engineering also. They have their special problem areas, but there's an enormous

amount of overlap. So Dimotakis and Rannie and Gary Leal [professor of chemical engineering, 1970-1989], who was there before, and I and Chris Brennen and Sabersky all share many interests.

COHEN: That's one of the strengths of Caltech. Being in small departments, people talk to each other.

ACOSTA: Yes, that's right.

COHEN: So you people developed all these courses over the years?

ACOSTA: Yes, based on notes. And it was much more common then in the sixties for Wiley [a book publisher] and others to come around and pester you for a book.

COHEN: That's not so common now.

ACOSTA: No, it isn't. The book business is way down. It's being treated differently now. There are still new books in fluid mechanics, to my amazement.

COHEN: Are there any students who particularly stand out in your mind, whom you had to deal with and who have gone out to do things that you'd like to mention as part of your record here?

ACOSTA: Yes, there surely are. That's one of the things I promised to sort out and write down, so I could do it justice. Sidney Leibovich is one of my early undergraduate students. He is at Cornell now and recently gave some seminars here in applied mathematics. There are lots. Can I think more coherently about that and come back to you later?

COHEN: Sure. Let me go on and ask you about your contributions that you felt were valuable here at Caltech, other than your teaching. I heard you talk about your new job interviewing students. What other sorts of things have you done for the institute?

ACOSTA: Oh, well, Shirley, that's kind of an embarrassing question. Other than take my

paycheck?

Well, the kinds of things we did in mechanical engineering and fluid mechanics research here with myself and Brennen and Sabersky, they were none of them for the most part following other leads. They all tended to be kind of new and opened up new problem areas, and I feel good about that. Other people are around now, doing those things. I was always able to bring in support for my research, and I always felt good about contributing that to the general Caltech enterprise. I was always active in our mechanical engineering society.

COHEN: The local or the national?

ACOSTA: The national one. Not so much the local one, although many times we'd serve as hosts for our dinner meetings and things of that sort. We had field trips through our laboratories many times. More on the national level, because our interest there was in helping to organize meetings or organize groups and sections of our society that needed our input. Because our interest is not so much in training engineers, but really in doing archival work that's necessary for good publications. So Milton Plesset and I, and later Chris Brennen, were all officers in the Fluids Engineering Division of the American Society of Mechanical Engineers [ASME]. And I was a founding member of what's called now the Ocean Engineering Group, which was an area of real interest for me. I was always interested in naval kinds of fluid mechanics problems, things connected to the propulsion of ships and flow around ships.

COHEN: Of course, that's part of your background.

ACOSTA: Yes, it is. That was the reason for the underwater, or ocean-engineering, area. There was a time when Warren Magnuson, the senator from Washington, had the Decade of Oceanography and there was a terrific upsurge of interest in ocean exploration, particularly deep submersibles.

COHEN: What year was this?

ACOSTA: This would have been in the 1960s. I found that quite interesting, so that's why I worked with this and helped set up this group. I got to know a lot of people interested in deep

diving things.

COHEN: Now, that was separate from what you were teaching here. That's an outside interest.

ACOSTA: Right, that was an outside interest.

COHEN: Where was this located on your end?

ACOSTA: Mainly working through ASME meetings and formulating conferences and things of that sort, and in high-speed surface transportation as well. Again, that was late sixties to seventies. That was an era when high-speed ships were perceived as the thing for the future, not only for transportation of goods, which didn't work out, but also there was a lot of interest on the part of the navy in high-speed ships. As it transpired, there was a period of ten years in which I worked a lot with local companies, as well as think-tank studies, on high-speed ships run by DARPA [Defense Advanced Research Projects Agency].

COHEN: Now, was this part of the cold war?

ACOSTA: Yes, that was part of the cold war thing. Well, there were a lot of cold war things that one could say were really bad. But there were some fascinating technical challenges, and it's impossible for scientists and engineers to resist those. Our most famous Caltech members and physicists still participate in those to this day. Nonetheless, it was kind of interesting, yet disappointing. None of those things seem to have come to pass in a technical sense. There are no significant fleets of high-speed hydrofoil boats or air-cushion vehicles in our country.

COHEN: Are they anywhere?

ACOSTA: There are more in Europe, where they serve a different need, as a passenger vessel. You can still get transport around the shores of Europe and in Russia with these hydrofoil-type craft.

These were all the kinds of things that guided and stimulated graduate-student research. Being exposed to these outside influences shows that there are intellectual things of interest to

pursue. So this was a source of inspiration for a lot of research, and continues to be.

One of those, which was not at all related to the cold war, was the question of rocket propulsion. There were events going on in Knapp's Hydraulic Machinery Laboratory that were unrecognized at the time, which led to serious problems in rocket propulsion and which have continued almost to this very day. It has to do with the stability of the rocket propulsion element itself and how to control that. Because, as I mentioned before, the release of power per unit volume is unprecedentedly high in these machines. So there are unprecedented new phenomena that have come along, which I started to work on; and then later Chris Brennen and Tom Caughey worked with us, doing new measurements that have been noted in lots of different places.

COHEN: Is any of this over at JPL?

ACOSTA: No, it was never in their charter to do this kind of propulsion work. Particularly when NASA got started and took over from the army, their focus was really different. There are other parts of NASA, though, that are concerned with these things. And so for twenty-some-odd years, as I mentioned, I had a connection with NASA Huntsville, which is the center for propulsion.

COHEN: In Alabama?

ACOSTA: In Alabama. They were very interested and supported us generously for many years.

COHEN: So that is your connection with NASA?

ACOSTA: Yes. JPL, from very early on, as you recall, was focused on deep-space science. There the propulsion item was not the driving force. That was done by other groups.

COHEN: What other schools or universities around the country would have similar kinds of programs to yours?

ACOSTA: Well, Penn State University and State College is certainly one. They have there a

situation somewhat more analogous to JPL, with their applied physics laboratory. It's a little different, because that is a federal contracts laboratory. They are concerned with many aspects of underwater propulsion.

COHEN: Have any of your students gone there?

ACOSTA: Yes, yes. Well, Blaine Parkin was director of that water-tunnel facility for a number of years. And we've had other students go there. Their work on underwater propulsion shares many of the same features of cavitation, two-phase flow phenomena. Difficult fluid-mechanical problems that we have with the liquid-rocket propulsion part.

COHEN: Anywhere else besides Penn where some of your students may have gone?

ACOSTA: Well, yes. They've gone to practically all the Ivy League schools and Big Ten schools, as well as industry. We still like industry, and it needs good leadership.

COHEN: Well, the [Caltech] Associates and alumni groups are very strong here at Caltech. And I'm sure many of them must be graduates of yours.

ACOSTA: Yes, they are, particularly locally. In early years, starting in the thirties and certainly carrying through the forties, mechanical engineering was the most popular undergraduate Engineering and Applied Science option. And as I mentioned last time, that popularity went through a sort of decline, but it certainly is there now.

COHEN: Any comments in general you'd like to make about your life here at Caltech?

ACOSTA: Honestly, I couldn't imagine teaching elsewhere, despite the many high-profile personalities. Life can always be difficult for personal reasons, but I could not imagine teaching and enjoying myself at any other place as I have here, because I think most everyone realizes that when you are here, if you are reasonably good at your job, why, you work for yourself and for what you think should be done at Caltech. And it is not so much a hierarchical place. We do not have so much straight up-and-down structure. Inevitably, that has to be changed, and has

changed somewhat, just to respond to external requirements. But really, I think all good departments are still there. People teach basically what they want to teach. People do the research basically that they want to do. It does get difficult in midlife to make an abrupt change in your career because of the necessity to continue to support students in areas that are perhaps not so well known. That's true in all walks of life.

COHEN: Of course. I think people here feel very strongly that their students go on to lead a productive life and not just as clones of the professor.

ACOSTA: That's right. And most of us work hard to make sure our students get access to jobs that are right for them. It's for that reason that I think the lack of a strong hierarchical structure has made this place so interesting and productive. And yes, the Engineering and Applied Science Division had an even more formless beginning than the other divisions did.

COHEN: So that's led to a strength, and not a weakness, in many ways.

ACOSTA: Yes, it has, especially during the growing phase. There was no formal division. There was engineering, and then the "applied science" is an addition, as you know from your history.

COHEN: That's right. I do know that when they had to decide on a name, they added the "applied science."

ACOSTA: That's right. We were not so sure about that, so it just happened. But there were no strong departments until relatively recent times. There was not a strong department of civil engineering or mechanical engineering. GALCIT was a separate entity, housed within this division. Civil engineering was not strong. Computer science was Gilbert McCann [professor of applied science, emeritus, d. 2003] to begin with. Electrical engineering was Royal Sorensen [professor of electrical engineering, d. 1965] and a very small group, and that became part of engineering after the war.

COHEN: It was connected with the physics division before that.

ACOSTA: Connected with physics, yes. And I think the intent there was clearly that the engineering division had to grow. And it did grow under the very benign leadership of Fred Lindvall, who had one secretary and carried around the whole business of the division in his back pocket and in his head.

COHEN: Proving the concept of benign neglect to be very good!

ACOSTA: Yes, it was. He was kind of laid back; he did not rule with an iron hand. He did everything by suggestion. When I joined the division, it was a typical kind of Lindvall approach: We met by chance, walking down the street, and he asked me if I would like to go on the staff, and I said, sure I'd like to do that, and that was that.

COHEN: That was your appointment.

ACOSTA: That was my appointment.

COHEN: And as you said previously, one didn't notice when tenure happened; it suddenly just appeared.

ACOSTA: That's right, it did. I think most of us my age would not relish having to go through the process that our young professors do now. It's pretty agonizing. Lots of angst. I think Caltech generally wants to try to minimize that, so we're very careful about the people we appoint to begin with, because we really want them to come and succeed. The same way we do with our freshmen and our beginning graduate students. We want them to come and succeed, because it changes everything, changes the whole way you look at your institution and the people you work with. There are famous schools that do otherwise, but that has not been our way.

COHEN: Probably that's why it's a pleasant place to be.

ACOSTA: Yes, I think everyone realizes you're all pulling in the same direction.

Back to management-related things. We did have to become more and more organized,

and so subgroups did form, in our case, under the chairman of the division. New options were formed. First, it was in applied mechanics; applied mechanics basically meant structures. And then there was one in civil engineering. And of course the applied physics part of the E&AS Division became separate. It was born that way. Electrical engineering was a separate option by that time. But the loose collection of us in mechanical engineering had different designations. Frank Marble was jet propulsion. So was Zukoski. I was mechanical and so was Sabersky. Don Hudson was both. Frank Marble was both, mechanical and jet propulsion. We talked with each other but not as a small group. We always met with civil engineering, applied mechanics, and now materials science. We would meet as this large group and discuss matters of joint interest: courses and students. We finally decided to form a mechanical engineering option, so that we could exercise more guidance about what undergraduate programs we wanted and in particular guide the teaching in this area, still with the idea of being a part of this extended and larger group. At Caltech, nothing else really makes sense. To have a narrow specialty in a school that's already a special school is just not our way. So the division did form a new option, and I was the first executive officer of that [1988-1993]. And that was starting from scratch, from our sort of higgledy-piggledy, wandering, random ends. It was interesting to try to form a more cohesive group as an outreach to the others. We started faculty meetings and we started rapprochement with our other groups so we would still stay together. And we were also able, through activities of ourselves, in particular Fred Culick and Rick [Richard C.] Flagan [Irma and Ross McCollum-William H. Corcoran Professor of Chemical Engineering and professor of environmental science and engineering], who was in our group at the time—he has since joined chemical engineering—to appoint six new faculty, and that made an enormous difference. And with those young people, we integrated our mechanical engineering shop. It had never had a central role in education; in fact, it didn't really know what it was. Was it to support the students, or was it to make things like the aeronautics shop and chemical engineering shop? Our research was neither fish nor fowl. But the new young staff seized this as a means of teaching. It really has become a very dynamic operation.

COHEN: Were these new assistant professors at Caltech? Or people who had been here?

ACOSTA: It was young appointees who seized this opportunity and have made it into what it is.

COHEN: What is this option called, again?

ACOSTA: It's mechanical engineering, but this refers to the design aspect of mechanical engineering, which had long been sort of a neglected field, because we had emphasized more of the analytic, the applied mechanics, or what was called engineering science, although that's not a very popular term anymore. It's not a good descriptive term. People in our division do things in their normal engineering work that at many institutions would be done in the science options. Yet at the same time there is a component of engineering, where you worry about how things are made and why they're made that way, and so on. Erik Antonsson [professor of mechanical engineering] was our first young appointee, and Joel Burdick [professor of mechanical engineering and bioengineering] is an honored teacher in that subject as well as in his own area of research, which is robotics.

Antonsson and Burdick teach design. And Melany Hunt [professor of mechanical engineering] came as a teacher in thermal dynamics and with her came Dave [David G.] Goodwin [professor of mechanical engineering and applied physics], who also works in thermal physics. These appointees all came in a fairly short length of time, and the students just reacted to that terrifically well. We now have a sense of where we're going and why we're doing it. We put money into our mechanical engineering teaching shop, as we call it. And we have more undergraduate students than we can possibly handle.

COHEN: Is that right? You're vying with electrical engineering.

ACOSTA: That's right. We are right next to electrical engineering in undergraduate popularity. The students find it exciting. They find it fun. And so I feel very good about that.

COHEN: That's a very fine legacy.

ACOSTA: We just made a new appointment from Stanford, in fluid mechanics this time [Tim Colonius, professor mechanical engineering—ed.]. I think our future is secure.

But nonetheless, Shirley, I think my colleagues do not want to see a narrow-based ME discipline as it might be, let's say, at a Big Ten school. Because everyone of us interacts with all

the other members of our immediate group in applied mechanics and civil engineering as well as beyond that, in aeronautics and computer science and elsewhere.

COHEN: Now, the chemical engineers are more with the chemists.

ACOSTA: Yes, their force comes from the chemist group pretty much, although there are individuals there who do work in our fields, and we talk with them, and we share seminars and get them to come visit us, like John Brady [Chevron Professor of Chemical Engineering], in particular, who works in an area of fluid mechanics that we respect and understand. And George Gavalas [professor of chemical engineering, emeritus]. And on occasion, not commonly, we've had our students take one another's courses both on the undergraduate and graduate level.

COHEN: Now, I cannot finish this interview without knowing what kind of boat you have.

ACOSTA: Yes, I can go on about that for quite some time. It's a cutter. A cutter is a boat that carries a mainsail, a jib, and a staysail. The main is farther aft than a sloop would have it. And it's an unusual cutter, in that it has two centerboards, one forward underneath the main mast and one all the way aft, so that you can control the external aerodynamics and the underwater hydrodynamics equally, with equal facility.

COHEN: Did you design this boat?

ACOSTA: No, I did not. I had a very dear friend who did. I did build it. My wife and I built it with our own hands, everything from the ground up. And that was an interesting thing. Anyone interested in engineering and science really should build a boat—gives you a feeling of great confidence.

COHEN: That's right. It has to float when you're finished. Have you made any long trips on this boat?

ACOSTA: No, I made a promise I would not ask my wife to go on a blue-water overseas cruise. And neither one of us was a spring chicken when we finished the boat. We were all exhausted at

that time. We started in ’76 and launched it in 1980. During that time, I was teaching one or two courses all the time. We teach year-round, except during the summer, here at Caltech in our division. Every quarter, we teach at least one course. I had graduate students doing research. I was chairman of my division in the American Society of Mechanical Engineers, and I was still consulting for these companies. I don’t know how we did it all.

COHEN: I guess you were busy.

ACOSTA: After four years I was completely exhausted.

COHEN: So it’s really a pleasure craft. You just do small trips.

ACOSTA: Oh, sure. We do the local Channel Islands and Catalina and San Diego. And I consider myself fortunate to be able to do that.

ALLAN J. ACOSTA

SESSION 4

May 19, 1994

Begin Tape 4, Side 1

COHEN: We wanted to backtrack a little to your research and teaching life at Caltech, and some of your recollections of your students and the work that they did with you.

ACOSTA: All right. It is certainly true that one of the pleasures of working at Caltech is working with bright, young people. And in the case of graduate students, I always consider them as younger colleagues rather than students, in the top-down implication of that phrase. For that reason, I was never able to have too many at once. I know some people, more elsewhere than at Caltech, who have ten or twelve PhD students. It's a mystery to me how that can work. I found that three or four exhausted my psychological and physical resources, because I work with them very closely. Usually every other day at least we would get together about one matter or another. So I never had too many. And they've gone various places. Many are in industry, some in government labs, some in teaching. You always remember the first ones, or the last ones, I suppose.

COHEN: Well, why don't we start with the first one. Who was your first student and when was that?

ACOSTA: My first PhD student was Richard Wade, a South African.

COHEN: What year would that have been?

ACOSTA: About 1965. He went into industry in the field of practical hydrodynamics and was very active in the high-speed ship developments by the navy and now works for Science Applications Incorporated [SAIC] in San Diego, where he is a chief scientist or something like that. Those were very interesting times. His work was done in the Hydrodynamics Laboratory, now run by Paul Dimotakis. We did some very interesting things, which were novel at the time.

In fact, some of his experiments have never been repeated.

COHEN: Does that mean they couldn't be repeated?

ACOSTA: No, it's because we had a unique facility there and were able to use it in a novel way to study some interesting phenomena that had not been quantified before.

COHEN: Can you briefly say what these phenomena were?

ACOSTA: Flows have cavitation present, which we've mentioned before. It's a mixture of liquid and the vapor that is formed, so it's boiling. These flows are inherently unsteady. They don't behave in a nice, steady, well-behaved, controllable manner. And the onset of this instability is still puzzling. The physical phenomena that cause the unsteadiness are poorly quantified, even to this day, and even the natural history of these events is poorly documented. So ours was among the first of those to try to start to quantify this phenomenon and the source of it. It's still a question of major concern to high-performance machines operating with liquids of all sorts. It's an ongoing process, because the fluid flow that represents this basic phenomenon is inherently a complicated one that cannot be easily modeled, even with the best of supercomputers, because we do not know the proper physics to put in.

COHEN: That's interesting. So you worked on this problem, but he must have solved something.

ACOSTA: Oh, sure, yes, he did. There are many references to his work, around the world actually. Others followed. Ramani Mani went to General Electric, where he runs the department in fluid mechanics research. Others are at Sandia [National Laboratories]. One of our most recent ones, Doug [Douglas P.] Hart, who graduated a year ago June, is now on the tenure track at MIT and making his way in applied fluid mechanics.

COHEN: And working on many of these same problems?

ACOSTA: On many of these same problems. We still cooperate today on a joint venture studying propeller cavitation problems, which we are working with here in our tunnel at Caltech. Joe

Katz is now a professor at Johns Hopkins in mechanical engineering. It's a small department at Johns Hopkins, about the size of our own. It has three Caltech professors there, one of whom is chairman.

COHEN: It's an offshoot of Caltech in some sense.

ACOSTA: Yes it is. Francis Clauser [Clark Blanchard Millikan Professor of Engineering, emeritus] was a former chairman of engineering there many years ago, before he came to Caltech. So those institutional connections are still vital. Joe Katz will be coming here shortly. He and Doug Hart and I are cooperating on this project with one of our students still here at Caltech.

COHEN: Which project is that?

ACOSTA: This is a program on studying cavitation on propellers. So we're using some of Joe Katz's techniques and some of his equipment, and Doug Hart's experience in working in the facility, where the graduate student, Beth [Elizabeth A.] McKenney, has another year of work to do.

COHEN: And you continue to supervise her work?

ACOSTA: Yes, I, together with Chris Brennen, supervise her work. I hope our sponsors will still find sufficient cause to give us some more money next year. These days, it's getting harder. I worry about the younger faculty starting out. It's much more difficult for them to establish themselves because the agencies themselves are rethinking their mission. And there are all kinds of directives from the top that cause doubt over where future support will come from. This is more true in engineering and applied areas, and areas requiring missions, than it is in the core science areas.

COHEN: I think there are problems there also.

ACOSTA: There are. So unfortunately, as the Chinese say, these are interesting times.

COHEN: Are the students aware of this when they come in? That it's going to be difficult?

ACOSTA: Yes, they are. That they are. They are much more aware. And I think we see fewer students going on for graduate work, because of the worry about that and the urgency they see in establishing themselves in the outside world in their careers. So our incoming class in mechanical engineering this fall is the smallest it's been in some time.

COHEN: Is that because you accepted fewer, or have fewer applied?

ACOSTA: No, we had a number of applications. We find our ability to support them reduced, so our acceptances are fewer. There's terrific competition for the best ones. Competition is becoming fiercer rather than less.

COHEN: With whom are you in competition?

ACOSTA: The top schools—Berkeley, Stanford, MIT, Princeton, Harvard, and Cornell.

COHEN: I see. Now, when you take a graduate student, which of these institutions do you like to take them from? Because there are differences, I think.

ACOSTA: There are differences, yes. Well, my own personal feeling is that the students who come from Stanford and Princeton are extremely well prepared. I think the students who come from Berkeley are perhaps not quite as well prepared as those from Stanford.

COHEN: Now, where do you look—in physics, in mathematics?

ACOSTA: Yes. Their background in physics and mathematics is not quite as strong as some of the other ones.

COHEN: I've heard that Cornell is very good in physics.

ACOSTA: Cornell is excellent, yes. We send students to Cornell, too, and they do very well

there. We have good connections to Cornell, and we share. We have Caltech professors there. One of my first undergraduate advisees is there in applied mathematics now.

COHEN: What is that person's name?

ACOSTA: Sidney Leibovich, a very distinguished person.

COHEN: How long has he been there?

ACOSTA: Oh, quite some time. He left here perhaps in 1960. Yes, that's an excellent place. I'm sending one of my current advisees on a three-year scholarship to Cornell this fall. So he will do well.

COHEN: I would also like to ask you a little bit about the consulting that you do. With whom do you do this? You did explain to me why you felt it was necessary for engineering people to keep up with consulting work. And that's interesting.

ACOSTA: Particularly in engineering, because we are ultimately concerned with making things or making decisions that get things made. And there are some who work in engineering, the result of whose work is to set policies, based upon procedures and based on science that is learned here. So, if you're not a part of that, it seems to me you are really kind of isolated from the main thrust and excitement of the basic field. My work is in applied fluid mechanics, and so I have in the past consulted with, and I consult regularly with, one of the largest pump companies in the world. It's the Byron Jackson division of BW/IP [Borg Warner International].

COHEN: BW/IP?

ACOSTA: BW/IP is an international company in fluid-handling products, with divisions in a number of countries and headquartered here in Los Angeles. I've known that company for many years, because when I was a graduate student, the owner of the company that became this company, the last private owner of that company, gave me his fellowship for graduate study.

COHEN: What was the name of that fellowship?

ACOSTA: His name was Keating and I was the first, and I think only, Keating Fellow. It was easy then to give money, because tuition was only $500 a year.

COHEN: Of course $500 meant much more then.

ACOSTA: Yes, it did. But the ratio of salary to tuition was different. I still maintain contact with that company, even this week as a matter of fact. I work very closely with the ABLE Corporation, which is run by a Caltech graduate, Elmer Ward. Basically, his company designs and builds specially engineered aerospace components. These are largely fluid-handling devices: actuators, motors, electromechanical things. I do a lot of analysis. In fact, I have some patents from them for things that are developed there. That goes back to 1953.

COHEN: So you've been with them a long time. These are very stable companies.

ACOSTA: Yes, and in former times Aerojet General, Sunstrand Aviation, the navy. A couple of the larger companies. Those are the important ones.

COHEN: And you continue to deal with these people?

ACOSTA: Yes. I find it exciting and I also kind of enjoy the competitive aspect of engineering, being able, or trying, to do something better than another organization. That's fun. It's fun to be able to use the things you think about and study. And it's also a lot of fun to show students what you are doing. They react very positively to that. I take them on field trips to visit these companies and other companies. So that makes it a very dynamic affair, associated with the real world.

COHEN: Now let's go back to something that we talked a little about much earlier, which was your year on Bikini Island as an ensign. Now that's a long time ago, but I think you had a unique experience.

ACOSTA: Yes, that was kind of unusual.

COHEN: Maybe you would like to say something else about that. You just referred to the fact that you did it and got out of it as soon as possible to get back to your academic work.

ACOSTA: Well, that's true. Let me try to think about that a bit. I'm sorry that I wasn't more receptive to all the trends and flow of ideas and so on that were going on. And I'm sorry I don't have more mementos of that. I did take some pictures. It was OK to take pictures of the burning boats, and I do have a few of those. Everyone at that time—I'm sure you remember this yourself—was still wondering if it was a good idea to have dropped the atomic bombs on Japan to begin with.

COHEN: Oh, I think those ideas still exist.

ACOSTA: Yes, we had our long discussions and arguments through the night. All of us did. Maybe the older people didn't, but the younger ones surely did. And seeing the result of all that at that time was really quite impressive.

COHEN: You mean the testing that went on?

ACOSTA: To see the results of the tests. That was for the ABLE test, which was the air drop test.

COHEN: What was that called?

ACOSTA: There were two tests, in 1946. ABLE and BAKER. This was the Joint Army-Navy Task Force. There was a vulgar translation of that, the acronym, which I will not repeat here.

COHEN: Maybe it's good to have it on record.

ACOSTA: No, I have to show you. We all got shirts saying we were at this Bikini test. It was a beautiful tropical island. Only last week, in the *New York Times*, there was an article about the Bikini Islanders' dole. They have a lot of money somehow that the government's given them,

but they don't have a place to spend it. And it's a beautiful lagoon, sixty miles around, something like that, twenty miles across.

COHEN: And is it still radioactive?

ACOSTA: Yes, and parts of it are gone. The subsequent H-bomb test was on a different island in the same island chain. And that island is gone. That was Operation Mike. Bikini Island is still there, but there's enough residual stuff around that they really can't go back and live; it's in the ground.

COHEN: Were you subjected to and aware of the fact that there must have been radiation and fallout? Was there any talk about that?

ACOSTA: Yes, there was talk about that. And I think the air drop occurred, I've forgotten exactly, about midday, maybe at ten in the morning; something like that. So we were all standing fifteen miles offshore. Everyone had eye protection and all that kind of stuff. We were advised that acceptable radiation levels for us were something like three milliroentgens per hour, something of that sort.

COHEN: And nobody contested that?

ACOSTA: Absolutely not. We believed everything we were told. In fact, we were a little bit put off once. I was in charge of a small vessel, twenty-five, twenty-six feet long, with two physicists on board who took radioactive samples and measured them locally. We puttered around these burning ships doing that. And there was a map, which I used to have a copy of, of what they thought the projected radioactivity would be relative to the bomb center. So one time the navy wanted to go over closer to this other interesting burning aircraft and take samples there. We requested to go over there and do that and we were told, no that was too hot, you can't go there. So we felt people were looking out for our interests and our safety. And of course radioactivity at that time didn't mean very much to me.

COHEN: Well, it didn't mean very much to any of us.

ACOSTA: No, we didn't know what dangers it represented or anything of that sort. We all thought it was quite exciting and awesome to see the damage that was so easily done. After that there was a lot of monitoring, but our work on that aspect of the monitoring was over pretty quickly.

COHEN: And as far as you know, people you were involved with there didn't suffer aftereffects?

ACOSTA: I had no knowledge of anyone who had any aftereffects. I have subsequently read that the second test, which was the underwater blast, was much more contaminating. After all, it's right there in the water. I have read that some people said that they had gotten exposed, but I don't have any firsthand knowledge of that in the first one. I don't have any firsthand knowledge of the second one, of any of the people I used to know or anything. I never had any feedback from that. Ruben Mettler would be an interesting one to ask about that aspect.

COHEN: What was he in charge of?

ACOSTA: I don't think he was in charge, I think he was on the staff of the person who was in charge. So he certainly had a much closer knowledge than I ever did.

COHEN: You know, I was just at the Smithsonian's American History Museum, and they had a display of the Bikini tests. So it has a prominent place in our history.

ACOSTA: Yes, I'd like to see that.