Modern English for Latest Technologies

最新
科技英语教程

吴宗森　陈永祥　夏国芳　编著

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编 著 者　吴宗森　陈永祥　夏国芳
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责任校对　王佳茜
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前　　言

人类历史上最近的一百年是世界科学技术发展突飞猛进的时期,从电视、汽车、飞机到电脑、卫星、机器人和太空飞船等各种新发明和新创造层出不穷。它们从根本上改变了人们的生活方式并极大地提高了人们的生活质量。马克思说"科学技术是生产力",邓小平同志进一步强调"科学技术是第一生产力"。在人类即将进入21世纪之际,科学研究已超越了国界,国际间的合作与交流已成为必不可少的手段。正在实施的国际空间站有好几个国家共同参与,全球定位系统、全球移动电话等都是国际合作的实例。我们的通信方式已今非昔比,不管在速度还是在数量上都比过去有大幅度的提高。但这一切都离不开语言这个基本工具,尤其是英语。英语作为交流的工具和信息的载体,它的重要性已随着科技的发展日趋增强。不管你是搞科技还是学科技,甚至搞人文科学的,都已身不由己地被各种科学技术所包围,而要熟练地运用先进科技为自己服务,英语是一条通往这个境界的"桥梁"。鉴于上述考虑,我们编写了这本教材。

本教材主要编录了美国 IEEE Spectrum, Time 和 Popular Science 等著名杂志近年来,特别是1998年以来发表的一些最新的科技文章。从移动电话、夜视器到电子鼻和人工眼,从高速公路、灵巧汽车到环境保护的新技术、语言计算机和多媒体技术,从国际空间站、精确计时到半导体光刻术和数字电路,从基因工程到外太阳系行星,几乎包括了当今理、工科最新的科技方向和科研动态。本教材还收罗了一篇介绍模糊理论之父——卢图夫·艾·扎德——的文章,使我们知道一位有创意的科学家是如何孜孜以求,克服困难,才攀登上科学的高峰。我们希望通过本书的学习,读者既能领略优秀科技文章的风采,又能把握最新的科技动态。最后作为附录,本教材还收集了 IEEE Professional Communication Society 有关科技工作者如何书写和发表科技论文以及如何口头宣读科技论文的文章。希望选修本课程的大学和研究生阶段高年级同学,以及所有科技工作者,通过对本教材的学习,会有耳目一新之感。

全书共16课(另加两篇附录),每课都有中文的提要、英文课文、作者简介、中文注释和简要的口头练习。课文的各段落按顺序都编了号。各段中较难懂或复杂的句子、词组和单词均依次打上*、**、***号。并以段落编号与*为序在课文后的注释中一一翻译成汉语,供读者学习参考之用。对于比较专业化的生词,我们也尽量收列在注释中。

我们三人中,一位多年在中国和美国从事电子科学的教学与研究及工程技术工作;一位长期从事中美教育和文化等方面的交流,另一位以非英语专业硕士生英语教学为毕生的事业。我们作为文、理学者在一起编著这本书,也许是一种新的尝试,从各自不同的专长出发把好关口,并在一起切磋讨论,力求为读者奉献一本值得阅读的英文科技教材。如果读者阅读本书后感到没有浪费时间,得到一些收获,那将是我们最大的欣慰。

最后,借此机会向所有支持和鼓励我们编写和出版本书的师长、同事、家人和朋友们表示衷心的感谢。向支持我们出版本书的南京大学出版社表示深切的谢意。

由于我们的水平所限,书中的错误在所难免,敬请读者不吝指正。

编著者

1999年6月于南京大学

卫星使
移动电话得心应手

阅读本课,你将会知道:

— 同步地球轨道(GEO)卫星和低地球轨道(LEO)卫星及中地球轨道(MEO)卫星有何差别?

— 对于移动电话,几颗卫星才足够?

— 为什么打移动电话时总有令人费解的延时?

— 移动电话是如何和卫星连通的?

Unit 1

Satellites Free the Mobile Phone

[课文]

1. *The moment of truth is near for a number of ambitious satellite ventures designed to enable users of handheld wireless phones to communicate with one another from any two points on earth. After years of increasing expectations, the first two systems of this kind are to start coming on line this year. **Within three more years, they may be joined by four or five others, though some of them are less than global in their scope.

2. The systems could change how business people, travelers, and others on the go maintain contact with friends, customers, or associates. *And those living in remote, sparsely populated areas poorly served by existing means of communication should also get their first taste of modern telephony.

3. Some of the satellite-based land mobile services are or will be worldwide; others cover broad geographical regions. *All are characterized by the magnitude of the capital being invested—in the billions of U.S. dollars—and by sweeping transnational business alliances. Virtually every one of these wireless efforts has given rise to international partnerships often involving satellite manufacturers, cellular service providers, electronic equipment companies, and telecommunications entities. **In addition, satellite systems are going into orbit to supply other services besides dialup telephones.

Roaming anywhere at will

4. What the systems seek to do is to extend access to cellular phone service to many more people, so that users of cellular-like handheld phones may communicate even in the absence of land-based cellular service. *Users of conventional terrestrial cellular service will be able to switch to satellite service when traveling beyond their local provider's coverage and without interruptions caused by incompatible or fragmented technical standards—a problem they now encounter when trying to roam among terrestrial service providers.

5. Cellular phone usage has exploded in recent years, leaping from four million worldwide in 1988 to an estimated 123 million in 1995; and that figure is expected to nearly triple by the time 2001 arrives. *Yet operators of the new mobile satellite systems estimate that anywhere from 40 percent to 60 percent of the world's population will at the turn of the century be living in areas without land-based cellular coverage.

6. Global versions of the new systems depart from the geosynchronous earth-orbit (GEO) satellites that have dominated commercial communication services since 1965. At present, about 180 commercial GEO satellites, divided into several scores of separate systems, ranging from one or two to more than a dozen satellites each, are circling in a band around the earth. From 35 800 km above the equator, they dispense many services, including TV distribution to terrestrial broadcasting stations and cable heads; direct-to-home TV; the relay of private network, maritime, and land mobile telecommunications; and, to a decreasing extent, long-haul telephony trunking.

7. A GEO satellite can illuminate about one-third of the earth so that three spacecraft equally spaced around the equator may cover the entire globe, with the exception of the polar regions. In the past, such satellites have not generated enough power to be able to complete a communications link with small handheld cellular-like phones on the ground.

8. Their new non-GEO counterparts will orbit the planet at lower altitudes. *The satellites' greater proximity to the earth greatly reduces what for many people is an annoyance— the lengthy signal propagation delay created by the long signal paths

stretching to the much higher-altitude GEO satellites.

9. *The lower-orbit systems require more satellites for continuous global coverage because of shrinking transmission footprints as orbit altitude declines. But individual satellites are smaller, lighter, and less expensive.

10. Satellites in low earth-orbit(LEO) are typically 500 km to 1 500 km above the earth, and the medium earth-orbit(MEO) versions are 5 000 km to 12 000 km high. *Further, whereas movement in synchronism with the earth's rotation makes GEO satellites appear stationary to earthbound observers, the others appear to be in constant movement.

How many are enough?

11. The number of satellites required by the global systems varies with altitude. The lowest-altitude system is counting on 66 plus six spares; a MEO system needs 10 plus two spares (the ICO system). *Atmospheric drag and radiation from the inner Van Allen radiation belt are expected to limit the orbital life times of LEO satellites, typically to five or eight years. Thus LEO systems will need replacements more often than will MEO satellites, which can expect to operate for 12 years. Even so, the cost for launching a smaller satellite into a lower orbit will be less than for the heavier, higher-altitude MEO satellites. The still heavier GEO satellites intended for regional system generally cost the most to launch—and build—but are designed for longer life times of 12-15 years.

12. Most subscribers will interface with one of these systems through a dual-mode, pocket-sized handset producing less than a half watt through an omnidirectional antenna. The units look and sound like cellular or personal communications system phones. *Users will be able to place or receive calls by way of the local terrestrial cellular provider or, in the absence of such service, by satellite.

Delays on the line

13. Signal propagation delay is a critical, and sometimes controversial, issue. In arriving at a concept for satellite cellular service, designers of the new global mobile systems rejected the GEO orbit on two counts. One was the high latency, or lengthy propagation delay from geosynchronous orbit. They considered this unacceptable to customers. The other was the difficulty in obtaining high link margins from this orbit. This margin is a measure of the difference between the actual power and the threshold power required for reception at a receiver. *The deeper they dug into the matter, the more convinced they became that a low earth-orbit was the best way of providing both low latency and high link margin.

14. The round-trip propagation delay for a GEO link is about 260 ms, compared to as little as 10 ms for Iridium, which has the lowest altitude of the pending cellular satellite systems. Other time delays also come into play. A typical Iridium call, for example, might incur a delay of about 160 ms, reflecting a combination of speech compres-

sion, processing, and propagation times. *In the extreme for Iridium, another 100 ms might be added for conversations between parties on opposite sides of the globe.

15. Time delay in the Iridium system varies with the path a phone call takes—this may not be simply up from the sender to a satellite and back down to the receiver. The path will depend on its starting and termination points, and on where the satellites are when a call is made. *Thus, a call can be handed over to the satellite ahead or behind it in orbit, or to a satellite on either side in adjacent orbits. **Handing calls off from one satellite to another permits calls to be placed or received from anywhere on earth free of ground intervention, a feature unique to Iridium.

16. *GEO satellites are burdened with the 260 ms time delay, but they can link subscribers directly within their large footprints. Total time delay can be kept within the 400 ms maximum for phone conversations generally accepted by designers as permissible. The propagation delay for MEO satellites is, of course, shorter than for GEO satellites, with the round-trip propagation time less than 100 ms.

17. Regional phone system operators, which employ GEO satellites, downplay the importance of signal delay. They maintain that users are willing to accept some perceptible delay. "The majority of survey respondents in our primary market research conducted in the coverage area has marked delay as a low priority issue," said Yousuf Al Sayed, project manager in Abu Dhabi, United Arab Emirates, for the regional system called Thuraya. Others dismiss the delay as nothing new for telephone users in areas of the world where regional systems are planned.

Linking calls

18. *The up- and down-link frequencies used between ground and the mobile service satellites vary among the systems but fall into bands approved for this mobile service by the International Telecommunication Union, Geneva. Uplinks from phones to non-GEO satellites are in the 1.610-1.6265-GHz band, downlinks to phones in the 2.4835-2.500-GHz band. If a call is to someone with a conventional fixed or mobile phone, the call will be converted and transmitted over another band, on a feeder link, from the satellite to a gateway, or ground station.

19. Feeder links up to a satellite typically are in the 5.091-5.250-GHz band; satellite-to-gateway down links are in the 6.875-7.055-GHz band. From there a call can be routed through the public switched telephone network (PSTN) and public land mobile network (PLMN) to the appropriate party. In addition, Iridium has crosslinks in the 23.18-23.38-GHz band for sending signals from one satellite to another.

20. To increase link margins, satellites transmit through high-gain antennas to provide adequate power at the handheld phone. Path loss gets worse the higher the satellite, because free-space losses increase as the square of the distance between satellite and ground receiver. *A geosynchronous satellite such as Thuraya, for instance, relies on a high-gain parabolic antenna, 12 meters in diameter, to produce an effective

isotropic radiated power (EIRP) of 56 dBW.

21. Further, the coverage area of mobile-system satellites is subdivided among a large number of individual spot beams, rather than spread across a single broad beam. This permits the reuse of frequency channels among noninterfering beams. It also increases the gain at the transmitting antenna, thereby increasing the power received at the small handheld terminals. But these benefits come at the cost of greater complexity in the satellites.

22. Unlike land-based cellular systems, the phone service of satellite mobile systems cannot penetrate to the core of large, modern buildings. This is due to the system's lower average link margins—16 dB for voice in Iridium's case (terrestrial cellular systems reached that stage a few years ago). *Iridium and other mobile system subscribers in such buildings will have to accommodate this system eccentricity. They will have to move closer to a window or doorway to establish at least near line of sight with the satellite for placing or receiving calls; a pager signal (in the Iridium system) will alert them to an incoming call. In the same situation, ICO phones will beep to advise the subscriber of an incoming call.

Globalstar: less is more

23. In contrast to Iridium, Globalstar designers preferred a simpler, less risky, and hence cheaper, spacecraft. It has neither onboard processing nor intersatellite communication links. Instead, as many functions as possible, including call processing and switching operations, are located on the ground where they are accessible for maintenance and future upgrades. The satellite's lower weight—450 kg—also could mean lower launch costs.

24. *The system almost covers the globe with a constellation of 48 satellites, roughly a third fewer than Iridium. They will be located in eight equally populated, circular orbits at 1414-km altitude. Another eight satellites will serve as spares. The orbits are inclined 52 degrees to the equator and spaced 45 degrees from one another along the earth's great circle.

25. *The inclined orbits concentrate communications between 70 degrees north and south latitude but at the sacrifice of polar coverage. "With a minimum number of satellites we cover the maximum amount of the earth's inhabited territory," explained John M. Klineberg, executive vice president of Space Systems Loral, in Palo Alto, Calif., which is building the system.

26. *The system operator, Globalstar LP, expects to have 44 satellites in orbit this year, despite the delay of last fall's maiden launch to allow for more extensive testing of telemetry and command functions. Partial commercial operations are planned by year end, full service by early next year. Globalstar is owned by five telecommunications service providers and seven telecommunications equipment and aerospace systems manufacturers. New York City's Loral Space and Communications, the largest stake-

holder, and Qualcomm Inc., San Diego, are the general partners.

27. *Globalstar's three-axis-stabilized satellites are trapezoidal, which, as with Iridium, assures multiple units will fit on a single launch vehicle. Each satellite is powered by two deployable solar arrays, generating 1.1 kW. By contrast, a regional GEO satellite like Thuraya requires more power—12 kW. **A magnetometer deployed from the spacecraft is used for attitude control, backed up by sun and earth sensors. A Global Positioning System (GPS) receiver supplies precise timing signals to clock frequency conversions in the spacecraft payload. GPS also determines the user's whereabouts for billing purposes.
28. Aboard the satellite is a well-established repeater design that acts as a "bent pipe" transponder, relaying signals directly to the ground with minimal processing. *This type of repeater is replaced by more complicated designs on satellites with a larger number of beams and where there is digital processing.
29. *Rather than directly connecting one caller to another by satellites, Globalstar downlinks calls received by a satellite over feeder links to a gateway. There they are processed and routed through the terrestrial infrastructure. But if the called party is another Globalstar subscriber, the call will be uplinked from the same or another gateway to a satellite for transmission to the destination.
30. *Fewer, and simpler, satellites in space mean more gateways on the ground, compared with, for example, Iridium. Thirty-eight gateways are in varying stages of completion for deployment worldwide; as many as 40 more are in the offing.
31. *Coupling into the local telecommunications infrastructure helps maximize the use of existing terrestrial communications services, Globalstar noted, and gives local service providers additional revenue opportunities. And working with indigenous providers should help Globalstar, as well as other satellite systems operators, gain local regulatory approval.
32. *Globalstar has set up franchises with more than a hundred local service providers covering about 88 percent of the world's population. By the close of 1997, it had secured approvals for operations in 19 countries, among them being the United States, Russia, China, and Brazil.
33. A pair of hexagonal phased arrays, one for uplink reception and the other for downlink transmissions, are mounted on the earth-facing deck of the satellite to form 16 independent beams on earth. To overcome limits on the frequencies available to users, Globalstar reuses the 16 MHz of bandwidth in each beam. "We have to reuse these frequencies as many times as we can to increase satellite capacity. We do this by assigning them to beams aimed at different parts of earth and reusing them," said Fred J. Dietrich, Globalstar's manager of system requirements in San Jose, Calif.
34. Globalstar also exploits path diversity to avoid outages caused if signals are blocked by surrounding obstacles. *Three or four 5.5-6-meter antennas at each gateway can

track simultaneously several satellites in view at any time. A switching system enables the same call to be put through at least two of the satellites. Multichannel receivers then can combine the signals into a single, coherent, potentially stronger signal.

35. *This capability, a result of using CDMA[code-division multiple access] technology, is singled out as one of Globalstar's competitive strengths. "We should have higher service quality because we make use of path diversity," noted Douglas G. Dwyre, the company's president. "When you're using TDMA [time-division multiple access] you cannot combine signals from more than one satellite, so competitors choose the best circuit from one satellite. With three or four satellites available, we can combine all the signals and use adaptive power control to put most of the signal through the strongest link. This power-efficient technique not only improves our capacity — it greatly improves our availability and should reduce dropouts."

[作者简介]

Barry Miller is a contributing editor of *IEEE Spectrum*. This article was published in *Spectrum*, March 1998.

[注 释]

1. (*moment of truth*:紧要关头,严峻考验的时刻; *handheld wireless phone*:手持无线电话)*一些雄心勃勃的人造卫星风险投资人打算让无线手机用户之间在地球任何两个地方通话,这个重大的关键的时刻快到了。**再过三年时间,其它四或五个(系统)会加入进来,尽管它们之中有些未必是覆盖全球的。
2. (*on the go*:忙个不停的;*maintain contact with...*:与……保持接触)*那些生活在边远、人口稀少、难以得到现有通信手段服务的人们也能得以首次尝试现代人电话术的乐趣。(*sparsely*:稀少地)
3. *所有这些(移动电话)服务都以耗资几十亿万美元之巨额和大规模的跨国商业联盟为特色。(*cellular service provider*:蜂窝电话经营者)**此外,卫星系统正在进入轨道,以提供除拨号电话以外的其它服务。
4. *当传统陆地蜂窝电话的用户旅行到他们当地经营者覆盖的范围以外时,即能切换到卫星服务上,而且不致因不兼容或分割的技术标准引起电话中断,而这是他们现在试图在陆地服务提供者之间漫游时遇到的问题。(*incompatible*:不兼容; *fragmented technical standards*:分割的技术标准; *roam*:漫游)
5. *然而新移动卫星系统的经营者估计,40%到60%的世界人口在世纪之交时将生活在陆基蜂窝电话覆盖区以外的地区。
6. [*geosynchronous earth-orbit* (*GEO*) *satellites*:同步地球轨道卫星; *maritime*:海上的; *to a decreasing extent*:以逐步缩减的范围; *long-haul telephony trunking*:长途电话中继]
7. (*illuminate about one-third of the earth*:约照射地球的三分之一)
8. *由于卫星更接近地球,从而大大地减少对许多人来说是一个烦恼的问题——由于信号传送到更高高度的GEO卫星信道而引起的漫长的信号传播延时。(*lengthy signal propagation delay*:漫长的信号传播延时)

9. *低轨道系统由于随着轨道高度降低，每个卫星的发射覆盖范围逐渐缩小，因而需要较多的卫星以便连接全球的覆盖。
10. *不仅如此，由于与地球自转同步的运动，从地球观察者角度看来，GEO 卫星是不动的，但是别的卫星则是在不断地运动。
11. *大气的拖动及内 Van Allen 辐射带造成的辐射估计使低地球轨道卫星的留轨寿命通常限制在 5 至 8 年。
12. （*dual-mode*：双模；*pocket-sized handset*：袖珍手机；*omnidirectional antenna*：无方向性天线）*用户将能通过当地陆地蜂窝电话经营商，或者在没有这种服务时通过卫星，拨打和接收电话。
13. *他们对这种情况了解得越深入，就越相信低地球轨道是提供低隐患及高连通余量的最好方式。（*latency*：隐患；*link margin*：连通余量）
14. （*pending*：在进行中的）*就铱星（*Iridium*）的最大值而言，当双方在地球两边时，通话有额外的 100 ms（延时）也许会加上去。
15. *因此，通话可能从一个卫星送到另一个在此轨道之前或之后的卫星，或者在地球两边邻近轨道的卫星。**把通话从一个卫星传送到另一个卫星可使打出和接收电话不受地球上任何地方干扰，这是铱星与众不同的独特之处。
16. *GEO 卫星为 260 ms 的延时受累，但它们能在自己广大的覆盖范围内把用户直接连接起来。
17. （*downplay*：贬低；*survey respondent*：调查答卷人）
18. *地面和移动服务卫星之间向上和向下的连接频率在这些系统中是不同的，但是都落在由日内瓦国际通信联盟为这个服务所批准的频域内。（*uplink*：上行线路；*downlinks*：下行线路；*feeder link*：支线；*gateway*：网间连接器）
19. ［*public switched telephone network*（*PSTN*）：公众电话转接网络；*public land mobile network*（*PLMN*）：公众陆地移动电话网络］
20. *例如，像 Thuraya 这样的同步卫星，依靠一个直径为 12 米的高增益的抛物线天线，产生 56 dBW 的有效各向同性辐射功率。
21. （略）
22. *铱星和其它移动系统的用户在这类建筑物里时，将不得不迁就这些系统的怪僻。（*a pager signal will alert them to an incoming call*：呼叫信号将使他们留心打进来的电话）
23. （略）
24. *该系统由 48 颗卫星（差不多比铱星少 1/3）组成的星座几乎覆盖了全球。
25. *倾斜的轨道把通信集中在南北纬 70°之间，但无法顾及南北极区。
26. *系统经营者，Globalstar LP，期望今年有 44 颗卫星进入轨道，尽管去年秋天首次发射推迟了，但却使得它能够进行更多的遥控和命令功能的试验。（*maiden launch*：首次发射；telemetry 遥控；*stakeholder*：赌金的保管者）
27. *Globalstar 的三轴稳定的卫星是梯形的，这种形状像铱星一样，更适合一箭多星的发射。**利用空间飞行器上的磁强计与太阳及地球上的传感器配合（对卫星）进行朝向控制。（*timing signal*：定时信号；*clock frequency conversion*：时钟频率转换；*spacecraft payload*：宇宙飞船的有效负载；*for billing purpose*：为收费目的）
28. *这种类型的中继器被卫星上更为复杂的设计所取代，这种设计采用了大量的波束并进行了数字信号处理。（“*bent pipe*” *transponder*：“弯管”响应器；*repeater*：中继器）
29. *Globalstar 不是直接把一个用户和另一个用户通过卫星连接起来，而是将卫星接收的通话向下经过网间连接器传给支线。
30. *比方说同铱星相比，空间卫星的减少和简单化就意味着地面上需要更多的网间连接器。

(*in the offing* = *in the near future*)

31. *Globalstar 注意到,与地区电信设施的配合,有助于最大限度地利用现有的陆地通信服务,而且让地区服务商有额外的收入机会。
32. *Globalstar 已经与一百多个地区服务商建立了特许经营权,服务范围约幅射全球人口的88%。
33. (略)
34. *每个网间连接器中的三或四个 5.5—6 米的天线,能在任何时候同时跟踪几颗同一视野中的卫星。(*path diversity*:路径多样化)
35. *利用 CDMA 技术而得到的这个能力,被认为是 Globalstar 独特的竞争优势。(*... is singled out as...*:……被挑选出来作为……;*dropout*:漏失)

[回答问题]

1. What are GEO, LEO and MEO? What are their altitudes respectively?
2. What are the orbital life times for GEO, LEO and MEO?
3. How many satellites are enough for each of them?
4. What makes signal propagate delay? How many ms are needed for each of them?
5. What are up- and down-link frequencies used between ground and the satellites for non-GEO?
6. Why are Globalstar's satellites designed to be trapezoidal?

第二课

卢图夫·艾·扎德 — 模糊理论之父

阅读本课，你将会知道：

— 什么是模糊逻辑和模糊理论？

— 卢图夫·艾·扎德是怎样发明模糊理论的？他成功的秘诀是什么？

— 为什么人们开始时都不接受他的理论？

— 他的理论在哪些方面得到了应用？其社会价值是什么？

Unit 2

Lotfi A. Zadeh

[课文]

1. The denunciations were sometimes extreme. "Fuzzy theory is wrong, wrong, and pernicious," said William Kahan, a highly regarded professor of computer sciences and mathematics at the University of California at Berkeley in 1975. "The danger of fuzzy theory is that it will encourage the sort of imprecise thinking that has brought us so much trouble."

2. *Another berated the theory's scientific laxity. "No doubt Professor Zadeh's enthusiasm for fuzziness has been reinforced by the prevailing political climate in the United States—one of unprecedented permissiveness," said R.E. Kalman in 1972, who is now a professor at Florida State University in Tallahassee. "**Fuzzification is a kind of scientific permissiveness, it tends to result in socially appealing slogans unaccompanied by the discipline of hard scientific work."

3. A multitude of other outspoken critics also disputed the theory of fuzzy logic, developed by Lotfi A. Zadeh in the mid-1960s. Some 20 years were to pass before the theory became widely accepted—capped by this year's award of the IEEE Medal of Honor to Zadeh "for pioneering development of fuzzy logic and its many diverse applications." Even today some critics remain. But Zadeh never wavered. He had found himself alone in his scientific opinions on several earlier occasions.

4. "There is a picture of me in my study, taken when I was a student at the University of Tehran," Zadeh told IEEE Spectrum. "I sit at a table, and above the table is a sign in Russian: ODIN, which means 'alone'. It was a proclamation of my independence."

Child of privilege

5. *Perhaps the confidence Zadeh had in his judgment despite some tough opposition, and his willingness to stand apart from the crowd, originated in a childhood of privilege. He was born in 1921 in Azerbaijan, then part of the Soviet Union, and moved to Iran at age 10. His parents—his father a businessman and newspaper correspondent, his mother a doctor—were comfortably well off. As a child, Zadeh was surrounded by governesses and tutors, while as a young adult, he had a personal servant.

6. His career goal, for as long as he can remember, was to be an engineering professor. He never considered going into industry, he said, because money was no problem. Rather, he thought of scientific and engineering research as a type of religion, practiced at universities.

7. Zadeh received an electrical engineering degree from the University of Teheran in 1942. But instead of taking the comfortable route—becoming a professor in Iran—he emigrated to the United States.

8. "I could have stayed in Iran and become rich, but I felt that I could not do real scientific work there," he told *Spectrum*. "Research in Iran was nonexistent."

9. After graduation, Zadeh had a business association with the U.S. Army Persian Gulf Command. That enabled him to be financially independent when he came to the United States to enroll in graduate school at the Massachusetts Institute of Technology (MIT) in Cambridge. "MIT didn't have many graduate students at the time," Zadeh recalled, "so it was fairly easy to get in, even though the University of Teheran had no track record."

10. *MIT, it turned out, was an easy ride after the demanding course work Zadeh had faced in Teheran. His choice of subject for his master's thesis, though, marked one of the first times he would sail against the prevailing technical winds. **He chose to study helical antennas, a subject deemed unreasonable by the professor who had taught him antenna theory. Undauntedly, Zadeh found another professor to supervise his work.

11. "I felt that my judgment was correct, and the judgment of people who supposedly knew much more about the subject than I did was not correct," Zadeh said. "This was one of many such situations. Helical antennas came into wide use in the '40s and '50s, and my judgment was vindicated."

12. By the time Zadeh received his master's degree in 1946, his parents had moved from Teheran to New York City. So instead of continuing at MIT, he searched out a post as an instructor at New York City's Columbia University and began his Ph.D. studies there. *His thesis on the frequency analysis of time-varying networks considered ways of analyzing systems that change in time. "It was not a breakthrough," he recalled, "but it did make an impact and opened a certain direction in its field."

13. What he views as his first technical breakthrough came in 1950, when, as an assistant professor at Columbia, he coauthored a paper with his doctoral thesis advisor, John R. Ragazzini, on "An extension of Wiener's theory of prediction." This analysis of prediction of time series is often cited as an early classic in its field. *This thesis introduced the use of a finite, rather than an infinite, preceding time interval of observation for subsequent smoothing and prediction in the presence of multiple signals and noises. This, and Zadeh's other work while he was at Columbia, made him a well-known figure in the analysis of analog systems.

Berkeley beckons

14. As Zadeh was much entrenched at Columbia, he surprised his colleagues when he packed up in 1959 and moved to the University of California at Berkeley.

15. "I had not been looking for another position," Zadeh said, "so the offer from Berkeley was unexpected." It came from electrical engineering department chairman John Whinnery, who called him at home over the weekend and offered him a position. "If my line had been busy, I believe I would still be at Columbia," Zadeh told Spectrum.

16. Whinnery recalls it slightly differently. He had heard from a colleague that Zadeh had been toying with the idea of leaving Columbia. Minutes later, Whinnery picked up the phone and called him, arranged to meet him in New York City for dinner, and soon afterward hired him. Berkeley was then growing rapidly, and Whinnery was on the lookout for young scholars who were considered brilliant in their fields. *Zadeh fit the bill.

17. For Zadeh, moving to Berkeley was a simple decision to make: "I was happy at Columbia, but the job was too soft. It was a comfortable, undemanding environment; I was not challenged internally. I realized that at Berkeley my life would not be anywhere near as comfortable, but I felt that it would be good for me to be challenged."

18. Zadeh has never regretted the decision. To this day he remains at Berkeley, although by now as professor emeritus.

19. At Berkeley, Zadeh initially continued his work in linear, nonlinear, and finite state

systems analysis. But before long he became convinced that digital systems would grow in importance. Appointed as chairman of the electrical engineering department, he decided to act on that conviction, and immediately set about strengthening the role of computer science in the department's curriculum. He also lobbied the electrical engineering community nationwide to recognize the importance of computer science.

20. Once again, he found himself fighting conventional wisdom. A number of departmental colleagues felt that the trend toward computer science was a fad, and that consumer science should not be assigned a high departmental priority. "They accused me of being an Yves St. Laurent," Zadeh recalled, "a follower of fads." Elsewhere, professors in the mathematics department, along with the head of the computer center, were lobbying to set up their own computer science department.

21. Zadeh fought this battle as he has fought others, with polite persistence, his former chairman recollected. "We had many differences of opinion when he was chairman," Whinnery said. "When he couldn't convince people, he would get upset, but [even now] you can only tell this by the expression on his face. He doesn't yell or scream. Then he goes ahead and does what he was going to do anyway. And mostly he's been right, particularly about the importance of computers in electrical engineering."

22. Said Earl Cox, chief executive officer of the Metus Systems Group, Chappaqua, N. Y., who has known Zadeh since the '70s: "I've never seen him anger anybody, even though he prides himself in going his own way, in thinking his own thoughts." (Zadeh is also known for encouraging others to be independent. He insists his graduate students publish in their own name, noted former student Chin L. Chang, who is now president of Nicesoft Corp., Austin, Texas. That practice goes against custom.)

23. Zadeh finally got his way in 1967: the name of the department was changed to electrical engineering and computer science (EECS). A separate computer science department was also established in Berkeley's College of Letters, but after a few years it folded and became absorbed into EECS.

Fuzzy is born

24. While he was focusing on systems analysis, in the early 1960s, Zadeh began to feel that traditional systems analysis techniques were too precise for real-world problems. In a paper written in 1961, he mentioned that a new technique was needed, a "fuzzy" kind of mathematics. At the time, though, he had no clear idea how this would work.

25. That idea came in July 1964. Zadeh was in New York City visiting his parents, and planned to leave soon for Southern California, where he would spend several weeks at Rand Corp. working on pattern recognition problems. With this upcoming work on his mind, his thoughts often turned to the use of imprecise categories for classification.

26. "One night in New York," Zadeh recalled, "I had a dinner engagement with some friends. It was canceled, and I spent the evening by myself in my parents' apartment. I remember distinctly that the idea occurred to me then to introduce the concept of grade of membership [concepts that became the backbone of fuzzy set theory]. So it is quite possible that if that dinner engagement had not been canceled, the idea would not have occurred to me."

27. *Fuzzy technology, Zadeh explained, is a means of computing with words—*bigger*, *smaller*, *taller*, *shorter*.** For example, *small* can be multiplied by a *few* and added to *large*, or *colder* can be added to *warmer* to get something in between.

28. Once the issue of classification had been solved, Zadeh could develop the theory of fuzzy sets quickly. Two weeks later he had a fairly fleshed-out group of concepts to present to his collaborator at Rand, Richard Bellman. "His response was enthusiastic," Zadeh said, "and that was a source of encouragement to me—though had he been very critical, I wouldn't have changed my mind."

29. Since he was Berkeley's electrical engineering department chairman at the time, and engaged in his struggle over the place of computer science at the university, Zadeh had little time to work on his new theory of fuzzy sets. He published his first paper in 1965, convinced that he was onto something important, but wrote only sparingly on the topic until after he left the department chairmanship in 1968.

30. Since then, fuzzy sets have been his full-time occupation. "I continue to be an active player," he said. "* I am not merely an elder statesman who rests on his laurels. I give many talks, and this puts me under pressure. I must constantly think of new ideas to talk about and keep up with what others are doing."

The Golden Fleece

31. Acceptance of fuzzy set theory by the technical community was slow in coming. Part of the problem was the name—"fuzzy" is hardly proper terminology. And Zadeh knew it.

32. "I was cognizant of the fact that it would be controversial, but I could not think of any other, respectable term to describe what I had in mind, which was classes that do not have sharp boundaries, like clouds," he said. "So I decided to do what I thought was right, regardless of how it might be perceived. And I've never regretted the name. *I think it is better to be visible and provocative than to be bland."

33. And, as expected, fuzzy theory did cause controversy. Some people rejected it outright because of the name, without knowing the content. Others rejected it because of the theory's focus on imprecision.

34. In the late 1960s, it even garnered the passing attention of Congress as a prime example of the waste of government funds (much of Zadeh's research was being funded by the National Science Foundation). Former Senator William Proxmire (D-Wis.), the force behind the Golden Fleece Awards that honored such government boondog-