Research Benchmarks

Funding University Research Operations and Infrastructure

Rhode Island Economic Policy Council

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Contents

Abstract

Funding for University of Rhode Island research operations and infrastructure is compared to funding for 133 universities. Total URI research funds from all sources increased 38% from 1980 to 1999; nationally, funds for academic research increased 139% over the same period.

Compared to other states, Rhode Island ranks 48th in State funds per capita spent on higher education operations, 50th in percentage of state higher education funds spent on academic research, and 50th in state funds per capita or state funds per $1000 personal income spent on academic research. To bring RI to the 1999 national *per capita* average of state funds for *higher education operations* would require a 43% ($61.7 million) annual increase. To bring RI to the national *per capita* average of state funds for *university research operations* would require a 412% ($21.6 million) annual increase.

URI research spending was compared to 133 universities—including all Carnegie Foundation Research I and II universities, all 1862 land grant universities, and 13 universities previously used by URI for peer analysis. URI has a higher dependency on federal funds for academic research operations (measured as percent of total research operating budget) than any of 92 public universities in the comparison group. URI spends more per capita than the national average on research operations in environmental and psychology fields, but less than average for engineering, physical science, mathematical science, computer science, life science, or social science fields.

Rhode Island per capita expenditures on buildings, laboratories, and equipment used for research are below national averages and significantly less than top 100 research universities. A minimum necessary investment in research building construction, laboratory renovation, and equipment replacement is estimated to be $11 million annually.

Several examples are presented to illustrate what URI might want to do to develop economically-oriented university research centers and university-affiliated industrial research parks. Analysis of other factors critical to growth in major research universities include commitment to attain national prominence; leadership at all organizational levels; state, federal, and industrial funding; and the ability to exploit institutional "natural advantages."

Preface

Modern research universities drive the New Economy. The 125 Carnegie Research Universities[(1)]—including most of the land grant universities[(2)]—are a small fraction of the Nation's nearly 4000 colleges, universities, and advanced technical schools, yet they produce most of the nation's academic research and most of the graduate-level training in the sciences and engineering. Of the 13 higher education institutions in Rhode Island, there are only two research universities—Brown and URI—and only URI is public. With its rich land grant traditions of applied research, practical education, and engaged extension, URI is Rhode Island's natural focal point for research investment in higher education.

Because Rhode Island must turn to knowledge and technology to prosper in the New Economy[(3)], URI needs the strongest possible research and training facilities in the sciences and engineering. URI holds the key to preparation of globally-competitive scientists and technicians. URI can be the primary source of the next generation of entrepreneurs who will help us start and grow new leading-edge businesses. The University is an important kernel around which the future economy will form.

Rhode Island, however, is failing to make the necessary investment so that URI can fulfill its vital role in the economy. This is most apparent in economically critical science and engineering fields. By failing to invest in URI research operations and infrastructure, the State hinders URI's potential entrepreneurship in business, the applied sciences, and engineering.

This document will show that total funding for URI has remained essentiall flat over the past 30 years, and that current levels of investment in research operations and infrastructure compare poorly to what other states are spending. The document includes models at other research universities for investment in research and examples for creative partnering with leading-edge businesses. The document is intended to stimulate discussion about benchmarks and targeted investments, and to ultimately promote interest in an entrepreneurial renaissance at URI.

The University as Economic Engine

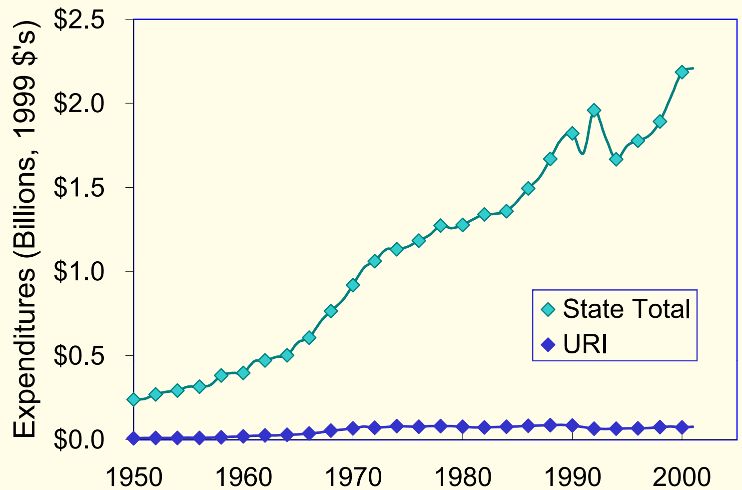
What follows assumes that the University of Rhode Island is an engine of the State's current and future economy; that the University's sciences and engineering[4]—and specifically on research and research-dependent graduate education—are key components of that economy; and that the comparative vitality of the research enterprise in Rhode Island's only public research University will be critical to how our economy fares in the future.

It is also assumed that to strengthen links between URI and the State economy, four components must be present. There must first be substantial **research operations**, well-supported continual commitments to a broad research agenda involving substantial numbers of faculty in areas relevant to the evolving state and regional economy. There must be up-to-date **research infrastructure**, including good buildings and laboratories and contemporary major items of equipment. To enhance the relevancy of both research and learning, there should also be an active extension of the university, characterized by campus support for **technology nurseries and commercialization** of intellectual properties produced by campus research. And finally—as is true in any quality organization—URI must adopt a hallmark commitment to perpetual customer **feedback**, in this case a continual evaluation of the quality of the product (the university's graduates and intellectual properties) and their relevance to the needs of the marketplace (the industries and government laboratories engaged in leading-edge technologies). These assumptions provide the framework for this document.

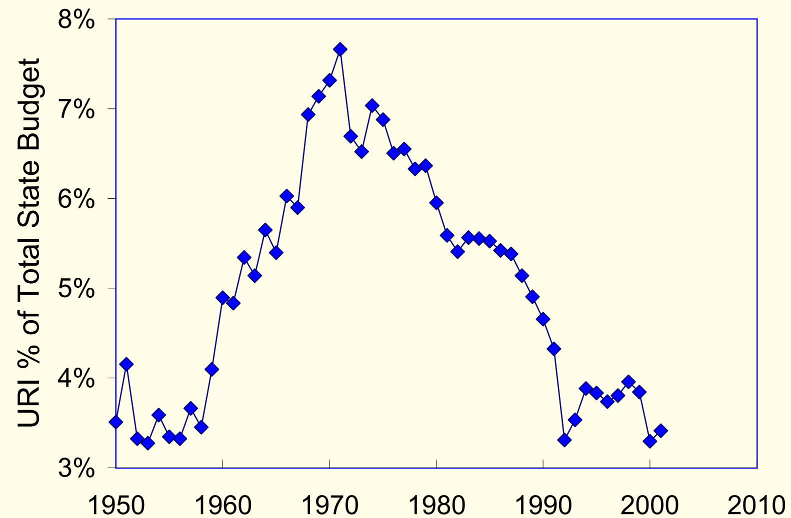
The effort to compare Rhode Island and its public research University to other states and universities—and to seek understanding from comparative "benchmarks" of how we might better support and use the University—is best preceded by an understanding of the fiscal evolution of the University as part of the State's budget over the past 30-50 years, as provided in the following brief historical overview.

What has happened to URI's research budget?

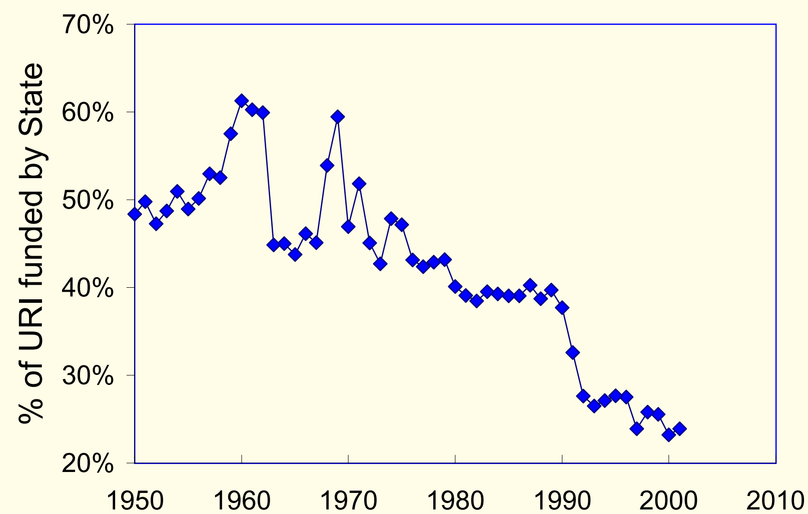
When State budgets grew, URI remained flat-funded. Inflation-adjusted, State general-revenue funding for the University grew exponentially in the 1960s: From 1960 to the early 1970s, URI's State funds nearly doubled twice. In 1971, real growth stopped. URI entered the new millennium with 3% less state support than it had in 1971: In contrast, the 2001 State budget had grown 116%[(5)].



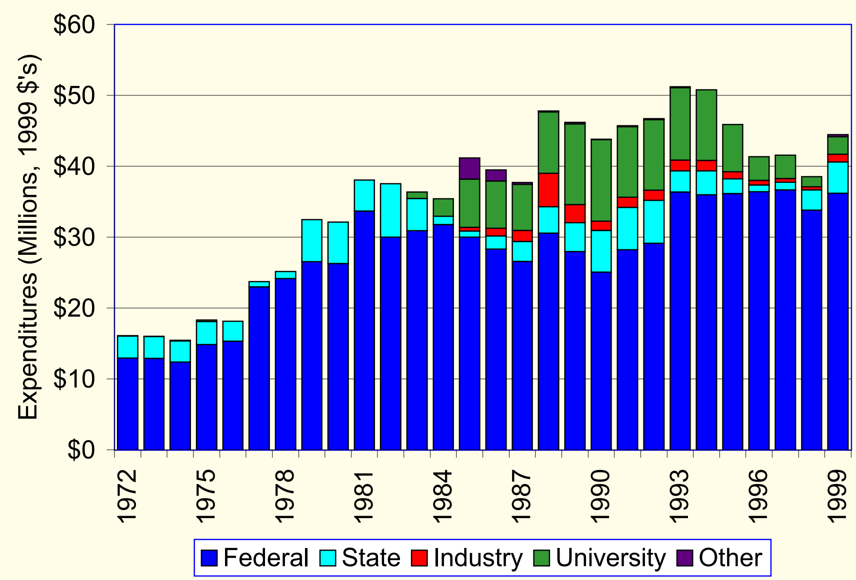
URI's State budget share has dropped since 1971.
As a result of flat funding, URI's budgetary importance has dropped steadily from its high of 7.7% of the Rhode Island total in 1971 to a low of 3.3% in 2000. Today's budget portion is similar to the 1950s, when URI was the State College, with a third of its present students and faculty[(6)].



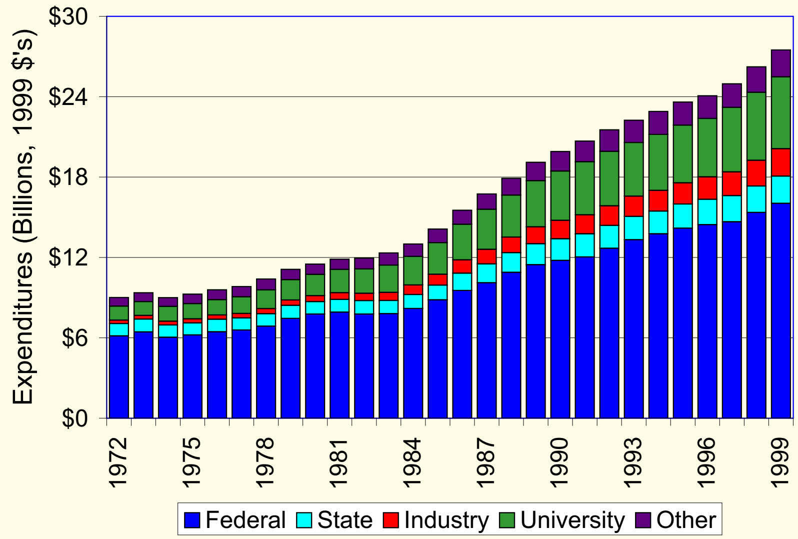
The State funded less of URI's budget every year. To keep up with inflation, the University raised tuition, competed for overhead-paying grants, and sought private donations to build its endowment[(7)]. Failure to increase state funding meant that URI has been moving from "State University" to "State-assisted University." On average, the State provided more than half of URI's funding in the 1950s and 60s, but provides less than one-quarter today[(8)].



Institutional support for research has declined. To balance its budget, URI has depended increasingly on tuition revenues. Inflation-adjusted institutional funds for research grew in the 1980s, but fell 87.5% from their 1990 peak by 1998. In 1997, URI had the highest percentage of federal sources for its research expenditures of any major research university. URI research expenditures from all funding sources have grown 38% over the past 20 years, while national averages (next page) have grown 139%[(9)].



URI's stagnant research expenditures contrast with national growth in spending. Nationally, spending on university research continues to grow, for all funding sources[9]. Adjusted for inflation, expenditures for science and engineering research conducted at U.S. universities have grown steadily for 30 years. Federal and State funds have grown less rapidly than the total, falling respectively from 68 and 10% of total in 1972 to 58 and 7% by 1999. Industry and University sources have grown from 3 and 12% of total in 1972 to 7 and 20% by 1999, while funding from private-non-profit foundations has remained at 7% of the total[10].



URI is not following national trends in funding research. Many Universities report that state budgets are lagging growth of University expenses[11]. Nevertheless, research expenditures have continued to grow as Universities compete for still-growing federal funds and use institutional funds on research, and as they collaborate with industry to fund on-campus research. URI is neither using more of its own funds nor obtaining industry funds to expand its research mission. URI has also seen little growth in federal funds in the 1990s.

Does Rhode Island differ from the nation because it is small or poor? By adjusting for population and income, we can compare our level of state and institutional investments to other states and other major universities to establish appropriate benchmarks for funding university research operations.

Benchmarks for Funding for Research Operations

How does Rhode Island compare to other states in support for university research operations?

Statewise comparisons. Rhode Island is the geographically smallest state. It is 43rd in population[(12)], 44th in gross state product[(13)], and 42nd in total personal income[(14)], yet Rhode Island per capita income is 18th in the nation (**Table 1**). Relatively speaking, RI is not poor!

How does Rhode Island compare in spending for Higher Education? Rhode Island ranked 48th in per capita state expenditures on higher education operations in 1999 (not including funds for buildings or major equipment, nor funds derived from tuition) (**Table 2**)[(15)]. 1999 RI per capita spending on higher education operations, $136.50, was 70% of the national average (of 50 states) of $195.

If Rhode Island were to have spent the national per capita average in state funds to support higher education operations—requiring an *increase* of $58.87 per capita (43.1%)—the State would spend an *additional* $61.7 million annually.

How does Rhode Island compare in spending for University research? State funds for university research include direct state contracts (i.e., grants from state agencies—to both public and private institutions) and all funds (from state appropriations, tuition, institutional foundations, etc.) spent internally for research at public institutions. The National Science Foundation provides on-line data on mean annual expenditure for all academic research in science and engineering[(9)]. To compare, we averaged expenditure data from 1997 to 1999 (latest available), adjusting each year to 1999 dollars.

- Rhode Island ranked 50th in percentage of higher education operating funds spent on research in 1999 (**Table 2**). RI's percentage (3.7%) is far below the national mean (of 50 states) of 13.1%.
- Rhode Island ranked 50th in per capita state support for university research (**Table 2**). RI's $5.01 was 19.5% of the national average (of 50 states) of $25.66.
- Rhode Island ranked 50th in state spending on University research aper $1000 of personal income (**Table 2**). RI's $0.18 was 18% of the national average (of 50 states) of $1.00.

If Rhode Island were to spend the national per capita average in state funds to support university research operations, an increase of 412% ($20.65 per capita), the State would spend an *additional* $21.6 million annually.

(Computing total national spending / national population produces a more conservative estimate than merely averaging the ratios for the 50 states. If the average per capita higher education operations state budget were computed as national total spending divided by national population, it would be $188 per capita, and RI would need an additional $54 million annually in state funds to become average. If the average per capita research state budget were computed as total states spending divided by U.S. population, it would be $22.15 per capita, and RI would need an additional $18 million annually in state funds for research to become average. If the average per $1000 of personal income level of support were taken as total national spending divided by total national personal income, it would be $0.80 per $1000 and RI would again need an additional $18 million annually in state funds for research to become average).

How does URI compare to other universities in support for its research operations?

Institutional comparisons. To allow broad comparison of URI without loosing tractability, we looked at 134 universities, listed in **Appendix Table 1**. This sample includes all 125 Carnegie Research I and II Universities[(16)], all 50 1862 Land Grant Universities[(17)], and 13 Universities previously used by URI for "peer group" comparisons[(18)]. The set includes 93 public universities and 77 universities with affiliated hospitals. We used NSF data on mean annual expenditures for academic research in science and engineering, averaged over 1997 to 1999, adjusted to 1999 dollars[(9)]. These institutions accounted for 84% of the national total spent on academic research from 1997 to 1999, including 84% of funds from the federal government, 82% from state governments, 81% from industry, 87% from institutional funds, and 79% from other sources.

Distribution of funding sources: Public versus Private, and the influence of affiliated hospitals. Public and private research institutions

Table 1. State 2000 population, 1999 Gross State Product, 1999 Personal Income and Per Capita Income, ranked. See text for sources.

State	2000 Population	Rank	1999 Gross State Product (Millions of $'s)	Rank	1999 Personal Income (Millions of $'s)	Rank	1999 Per Capita Income	Rank
Alabama	4,447,100	23	115,071	25	100,385	24	22,573	41
Alaska	626,900	48	26,353	45	17,736	47	28,291	14
Arizona	5,130,600	20	143,683	23	120,287	25	23,445	37
Arkansas	2,673,400	33	64,773	33	56,724	33	21,218	47
California	33,871,600	1	1,229,098	1	989,590	1	29,216	12
Colorado	4,301,300	24	153,728	21	127,904	22	29,736	9
Connecticut	3,405,565	29	151,779	22	129,780	21	38,108	1
Delaware	783,600	45	34,669	41	23,135	44	29,523	11
Florida	15,982,378	4	442,895	5	419,800	4	26,266	24
Georgia	8,186,453	10	275,719	10	212,806	11	25,995	26
Hawaii	1,211,537	42	40,914	39	32,641	40	26,941	19
Idaho	1,293,953	39	34,025	43	28,627	43	22,124	45
Illinois	12,419,293	5	445,666	4	377,650	5	30,408	7
Indiana	6,080,485	14	182,202	15	155,448	16	25,565	30
Iowa	2,926,324	30	85,243	30	73,453	30	25,101	33
Kansas	2,688,418	32	80,843	31	70,876	31	26,364	22
Kentucky	4,041,769	25	113,539	26	92,000	26	22,762	40
Louisiana	4,468,976	22	128,959	24	99,855	25	22,344	42
Maine	1,274,923	40	34,064	42	30,803	41	24,160	36
Maryland	5,296,486	19	174,710	16	168,168	15	31,751	5
Massachusetts	6,349,097	13	262,564	11	219,386	10	34,554	2
Michigan	9,938,444	8	308,310	9	277,214	9	27,893	17
Minnesota	4,919,479	21	172,982	17	146,810	17	29,843	8
Mississippi	2,844,658	31	64,286	34	57,272	32	20,133	50
Missouri	5,595,211	17	170,470	18	144,389	18	25,806	27
Montana	902,195	44	20,636	47	19,419	45	21,524	46
Nebraska	1,711,263	38	53,744	36	45,061	36	26,332	23
Nevada	1,998,257	35	69,864	32	56,094	34	28,071	15
New Hampshire	1,235,786	41	44,229	38	37,626	39	30,447	6
New Jersey	8,414,350	9	331,544	8	290,004	8	34,465	3
New Mexico	1,819,046	36	51,025	37	37,991	37	20,885	49
New York	18,976,457	3	754,590	2	616,878	2	32,508	4
North Carolina	8,049,313	11	258,592	12	202,109	13	25,109	32
North Dakota	642,200	47	16,991	50	14,747	49	22,964	38
Ohio	11,353,140	7	361,981	7	305,855	7	26,940	20
Oklahoma	3,450,654	27	86,382	29	77,093	29	22,342	43
Oregon	3,421,399	28	109.694	27	89.398	28	26,129	25
Pennsylvania	12,281,054	6	382,980	6	343,263	6	27,951	16
Rhode Island	1,048,319	43	32,546	44	29,066	42	27,726	18
South Carolina	4,012,012	26	106,917	28	91,463	27	22,797	39
South Dakota	754,844	46	21,631	46	18,358	46	24,321	35
Tennessee	5,689,283	16	170,085	19	140,094	20	24,624	34
Texas	20,851,820	2	687,272	3	537,857	3	25,794	28
Utah	2,233,169	34	62,641	35	49,573	35	22,199	44
Vermont	608,827	49	17,164	49	15,345	48	25,205	31
Virginia	7,078,515	12	242,221	13	204,769	12	28,928	13
Washington	5,894,121	15	209.258	14	174,877	14	29,670	10
West Virginia	1,808,344	37	40,685	40	37,802	38	20,904	48
Wisconsin	5,363,675	18	166,481	20	143,705	19	26,792	21
Wyoming	493,782	50	17,448	48	12,644	50	25,606	29
	Total: 280,849,744		Mean: 185,063		Mean: 155,277		Mean: 26,407	

Table 2. State funds for Higher Education Operating and University research, and spending per capita and per $1000 of income. See text for sources.

State	State Funds for Higher Education Operating ($1000s, 1999)	Per Capita Higher Educ. Operating (State $'s)	Rank	State Funds for Univ. Research (Mean 1997-1999, $1000s, 1999 $'s)	% of State H. Ed. Funds Spent on Research	Rank	Per Capita State Funds For University Research	Rank	State Funds For Univ. Res. $1s per $1000 Pers. Income	Rank
Alabama	1,037,680	233.34	11	90,446	8.72	42	20.34	31	0.90	27
Alaska	170,403	271.82	3	31,927	18.74	8	50.93	3	1.80	5
Arizona	836,389	163.02	39	158,136	18.91	6	30.82	14	1.31	13
Arkansas	556,659	208.22	18	55,655	10.00	38	20.82	30	0.98	25
California	7,250,661	214.06	15	785,602	10.83	31	23.19	25	0.79	31
Colorado	682,210	158.61	41	86,528	12.68	25	20.12	32	0.68	34
Connecticut	623,692	183.14	29	66,408	10.65	33	19.50	34	0.51	45
Delaware	164,115	209.44	17	24,423	14.88	15	31.17	12	1.06	19
Florida	2,501,857	156.54	42	269,287	10.76	32	16.85	39	0.64	37
Georgia	1,483,818	181.25	30	297,997	20.08	4	36.40	8	1.40	11
Hawaii	322,258	265.99	7	48,063	14.91	14	39.67	6	1.47	9
Idaho	266,522	205.98	19	36,153	13.56	20	27.94	19	1.26	15
Illinois	2,411,068	194.14	22	220,043	9.13	39	17.72	38	0.58	39
Indiana	1,147,819	188.77	27	154,227	13.44	21	25.36	23	0.99	23
Iowa	784,987	268.25	5	142,371	18.14	10	48.65	4	1.94	3
Kansas	604,704	224.93	12	106,091	17.54	11	39.46	7	1.50	7
Kentucky	888,700	219.88	13	119,169	13.41	22	29.48	16	1.30	14
Louisiana	859,036	192.22	25	145,986	16.99	12	32.67	11	1.46	10
Maine	199,149	156.20	43	14,734	7.40	47	11.56	47	0.48	46
Maryland	942,748	177.99	31	176,112	18.68	9	33.25	10	1.05	20
Massachusetts	975,360	153.62	44	69,773	7.15	48	10.99	48	0.32	48
Michigan	1,882,500	189.42	26	278,887	14.81	16	28.06	18	1.01	22
Minnesota	1,239,394	251.94	10	108,580	8.76	40	22.07	26	0.74	32
Mississippi	751,195	264.07	8	56,502	7.52	46	19.86	33	0.99	24
Missouri	919,548	164.35	37	118,009	12.83	24	21.09	28	0.82	29
Montana	129,929	144.01	47	30,371	23.38	2	33.66	9	1.56	6
Nebraska	440,095	257.18	9	102,822	23.36	3	60.09	1	2.28	1
Nevada	290,363	145.31	45	32,113	11.06	29	16.07	40	0.57	41
New Hampshire	91,156	73.76	50	17,156	18.82	7	13.88	46	0.46	47
New Jersey	1,453,937	172.79	32	162,375	11.17	28	19.30	35	0.56	42
New Mexico	517,261	284.36	1	56,635	10.95	30	31.13	13	1.49	8
New York	3,104,892	163.62	38	192,003	6.18	49	10.12	49	0.31	49
North Carolina	2,149,972	267.10	6	227,363	10.58	34	28.25	17	1.12	18
North Dakota	173,107	269.55	4	28,244	16.32	13	43.98	5	1.92	4
Ohio	1,934,587	170.40	33	203,357	10.51	35	17.91	37	0.66	35
Oklahoma	725,450	210.24	16	101,787	14.03	19	29.50	15	1.32	12
Oregon	556,412	162.63	40	71,922	12.93	23	21.02	29	0.80	30
Pennsylvania	1,773,094	144.38	46	184,243	10.39	36	15.00	43	0.54	43
Rhode Island	143,100	136.50	48	5,254	3.67	50	5.01	50	0.18	50
South Carolina	777,801	193.87	24	110,515	14.21	18	27.55	21	1.21	16
South Dakota	125,882	166.77	36	11,020	8.75	41	14.60	44	0.60	38
Tennessee	957,970	168.38	35	81,186	8.47	43	14.27	45	0.58	40
Texas	3,527,867	169.19	34	440,531	12.49	26	21.13	27	0.82	28
Utah	489,173	219.05	14	59,360	12.13	27	26.58	22	1.20	17
Vermont	59,173	97.19	49	14,648	24.75	1	24.06	24	0.95	26
Virginia	1,299,919	183.64	28	132,423	10.19	37	18.71	36	0.65	36
Washington	1,146,399	194.50	21	91,600	7.99	44	15.54	41	0.52	44
West Virginia	362,261	200.33	20	27,810	7.68	45	15.38	42	0.74	33
Wisconsin	1,040,341	193.96	23	148,607	14.28	17	27.71	20	1.03	21
Wyoming	139,711	282.94	2	26,992	19.32	5	54.66	2	2.13	2
	Total: 52,912,324	Mean: 195.38		Mean: 124,429	Mean: 13.08		Mean: 25.66		Mean: 1.00	

Public and private universities differ in how they fund research (Table 3).

- Of universities with expenditures for science and engineering research in the 1990s, 392 **public** institutions (57%) spent **68%** of total research dollars.
- **State governments** invested in research mostly within their own public institutions, which spent 91% of state agency grants.
- Public institutions also spent more **institutional** funds (derived from tuition, state appropriations, etc.) on research compared to private (24% versus 9% of institutional total).
- Private institutions depended more heavily on **federal** funds than public (72 versus 52% of institutional).
- The distribution of funding sources is affected by status as public or private more than it is by an affiliated hospital / medical school.

Table 3. University research spending in 1999 by **percentage,** from major sources.

	Federal	State	Industry	University	Other
All Universities (n=688; Total=$27.49 Billion)					
	58.4	7.4	7.4	19.5	7.3
All **Public** Universities (n=392; Total=$18.63 Billion)					
	51.9	9.9	7.3	24.3	6.6
Public, with hospital (n=32; Total=$5.10 Billion)					
	57.9	*5.0*	*7.0*	*20.6*	*9.4*
Public, without hospital (n=360; Total=$13.53 Billion)					
	49.1	*11.8*	*7.4*	*25.7*	*5.5*
All **Private** Universities (n=296; Total=$8.86 Billion)					
	72.0	2.0	7.8	9.4	8.8
Private, with hospital (n=28; Total=2.81 Billion)					
	71.0	*1.6*	*11.1*	*7.9*	*8.4*
Private, without hospital (n=268; Total=$6.05 Billion)					
	72.5	*2.2*	*6.3*	*10.2*	*8.9*
Percentage of this funding source spent in public universities:					
	60.3	91.3	66.3	84.4	61.2

differ in how they fund research. For example, in 1999 (see **Table 3** and sidebar) states spent 91% of their state agency research grants in public institutions. States also permit public institutions to spend money directly on research, creating significant differences in the relative amount of "institutional" funds spent on research. Differences in funding patterns (i.e., percentage of funds from each major source) are relatively unaffected by affiliation with a hospital.

"State" versus "Institutional" funds. NSF distinguishes between "state and local" (simply "state" in what follows) and "institutional" funds. Whether "institutional" expenditures are derived from tuition or the institution's endowment (the only options in private universities) or from state legislative line items for research (i.e., in public institutions), the funds are virtually indistinguishable from state funds allocated through state agency budgets as grants to the university. For example, if a state wants research on automated systems to control highway traffic, it can elect to fund this through a state Department of Transportation grant (which NSF then lists under "State & Local") or it can fund the institution directly for an internal "Transportation Research Center" (which NSF then lists under "Institutional"). Institutional funds make up a relatively higher proportion of research expenditures in public universities (24% versus 9% in private universities, **Table 3**).

URI's dependency on federal funds for research. From 1997 to 1999, 86% of URI's research expenditures came from federal funds: Only six institutions in our sample, including none of the 92 other public universities and none of the 49 other state land grant universities, show a higher dependency on federal funds (**Appendix Table 2**). Conversely, none of the 92 public universities or 49 land grants had a smaller percentage of research funds coming from institutional sources than URI. Adding state grants (52 of the 92 public universities had a higher percentage of funds from state agencies than URI) was insufficient to lift URI or Rhode Island from the bottom rank of state research investments (**Table 2**). URI has not significantly compensated with funds from industry: 88 of the other 92 public institutions had a higher percentage of research funds coming from industry.

Funding for research, by field. **Table 4** compares the research profile of URI to the national research profile, using NSF data on total research and development expenditures by field[19], with means from 1997 to 1999, in 1999 dollars. NSF reports R&D expenditures under major fields—engineering and seven for science—with subfields for engineering, and physical, environmental, life, and social sciences. Data are for operations, and do not include funds for buildings or major items of equipment (see next section).

Every university is distinct, and there is no *a priori* best pattern of internal investment by scientific field. The Ocean State is markedly different from the Lone Star State, for example, and the research profile of URI is naturally different from that of Texas A&M. Accordingly, URI has a substantial level of research activity in oceanography, for example: URI's per capita expenditures (from all funding sources) for oceanography are nearly ten times the national average.

In general, URI's *total* per capita expenditures for research operations ($39.62 per capita, with 86% from federal sources) are only 42% of the national average of $93.25[9]. URI exceeds national per capita operational expenditures only in environmental sciences (355% of national average) and psychology (260%). URI is under national average per capita operational expenditures in all fields of engineering (24% of average over all subfields, with no expenditures for aeronautics, bioengineering/biomedical, and materials research). URI has very low relative expenditures for mathematical sciences (0.12% of national average) and computer sciences (6%). The life sciences (14% of national average) show very low relative expenditures in biological and medical sciences (7.5% and 5.2% of national, respectively).

Table 4. Total separately budgeted R&D expenditures in the sciences and engineering, by field, using means for 1997 to 1999, adjusted for inflation to 1999 $'s.

	Nation			Rhode Island			RI per capita
Field of Science / subfield	Mean ($1000s)	$'s per capita	% of Total	Mean ($1000s)	$'s per capita	% of Total	as % of National per capita
Engineering	$4,113,583	$14.62	15.68%	$3,706	$3.53	8.92%	24.18%
Aeronautical & Astronautical	*$255,990*	*$0.91*	*0.98%*	*$0*	*$0.00*	*0.00%*	*0.00%*
Bioengineering/Biomedical	*$106,480*	*$0.38*	*0.41%*	*$0*	*$0.00*	*0.00%*	*0.00%*
Chemical	*$335,696*	*$1.19*	*1.28%*	*$482*	*$0.46*	*1.16%*	*38.55%*
Civil	*$505,269*	*$1.80*	*1.93%*	*$706*	*$0.67*	*1.70%*	*37.49%*
Electrical	*$1,018,231*	*$3.62*	*3.88%*	*$646*	*$0.62*	*1.55%*	*17.02%*
Mechanical	*$577,722*	*$2.05*	*2.20%*	*$409*	*$0.39*	*0.99%*	*19.02%*
Metallurgical & Materials	*$393,882*	*$1.40*	*1.50%*	*$0*	*$0.00*	*0.00%*	*0.00%*
Other, not elsewhere classified	*$920,314*	*$3.27*	*3.51%*	*$1,463*	*$1.40*	*3.52%*	*42.67%*
Physical sciences	$2,515,571	$8.94	9.59%	$898	$0.86	2.16%	9.58%
Astronomy	*$330,481*	*$1.17*	*1.26%*	*$0*	*$0.00*	*0.00%*	*0.00%*
Chemistry	*$882,601*	*$3.14*	*3.36%*	*$523*	*$0.50*	*1.26%*	*15.90%*
Physics	*$1,105,159*	*$3.93*	*4.21%*	*$366*	*$0.35*	*0.88%*	*8.90%*
Other, not elsewhere classified	*$197,329*	*$0.70*	*0.75%*	*$9*	*$0.01*	*0.02%*	*1.24%*
Environmental sciences	$1,634,043	$5.81	6.23%	$21,613	$20.62	52.04%	355.08%
Atmospheric sciences	*$268,173*	*$0.95*	*1.02%*	*$797*	*$0.76*	*1.92%*	*79.78%*
Earth sciences	*$508,384*	*$1.81*	*1.94%*	*$85*	*$0.08*	*0.21%*	*4.50%*
Oceanography	*$569,019*	*$2.02*	*2.17%*	*$20,704*	*$19.75*	*49.85%*	*976.78%*
Other, not elsewhere classified	*$288,467*	*$1.03*	*1.10%*	*$27*	*$0.03*	*0.07%*	*2.51%*
Mathematical sciences	$308,266	$1.10	1.17%	$1	$0.00	0.00%	0.12%
Computer sciences	$781,943	$2.78	2.98%	$176	$0.17	0.42%	6.05%
Life sciences	$14,785,280	$52.54	56.34%	$7,817	$7.46	18.82%	14.19%
Agricultural sciences	*$2,025,748*	*$7.20*	*7.72%*	*$4,188*	*$3.99*	*10.08%*	*55.50%*
Biological sciences	*$4,649,573*	*$16.52*	*17.72%*	*$1,301*	*$1.24*	*3.13%*	*7.51%*
Medical sciences	*$7,555,921*	*$26.85*	*28.79%*	*$1,473*	*$1.40*	*3.55%*	*5.23%*
Other, not elsewhere classified	*$554,037*	*$1.97*	*2.11%*	*$855*	*$0.82*	*2.06%*	*41.45%*
Psychology	$441,265	$1.57	1.68%	$4,282	$4.08	10.31%	260.49%
Social sciences	$1,186,247	$4.22	4.52%	$1,056	$1.01	2.54%	23.90%
Economics	*$267,158*	*$0.95*	*1.02%*	*$804*	*$0.77*	*1.94%*	*80.79%*
Political science	*$186,532*	*$0.66*	*0.71%*	*$27*	*$0.03*	*0.07%*	*3.89%*
Sociology	*$262,394*	*$0.93*	*1.00%*	*$1*	*$0.00*	*0.00%*	*0.07%*
Other, not elsewhere classified	*$470,164*	*$1.67*	*1.79%*	*$224*	*$0.21*	*0.54%*	*12.80%*
Other sciences, n.e.c.	$475,883	$1.69	1.81%	$1,986	$1.89	4.78%	112.02%
Total	$26,242,080	$93.25	100.00%	$41,535	$39.62	100.00%	42.49%

Benchmarks for Funding University Research Operations. Academic research expenditure data reflect investment in scientists, technicians, research aides and graduate students, and the expendable supplies and equipment needed for universities to conduct science and engineering research. Rhode Island is investing less in academic research than any other state, after adjusting for state population and income. Without State investment in research operations, URI scientists are at a competitive disadvantage, which may in part explain 20 years of slow growth of federal funds (and stagnation since the early 1990s) at URI, over a span when available funds have doubled (see page 4).

To have leading edge science and engineering, URI needs a robust research agenda. Funding benchmarks for operations (based on the above, in 1999 $'s), with mean of 50 states as the goal, are these:

- Attaining an average per capita level of state support for higher education operating expenses would require a 43% increase, or $58.87 per capita annually (total increase $61.7 million).

- Attaining an average per capita level of state support for university research operations would require a 412% increase, or $20.65 per capita annually (total $21.6 of the $61.7 million increase to higher education).

Competition to attract and retain faculty and research associates—competition between URI and leading research universities and the private sector—is critically dependent upon investment of state and institutional funds. Having the lowest level of state and institutional support of any major public research university is a competitive disadvantage for both the University and the State. The comparative underinvestment in operational support for research at URI will not create a competitive URI or a sound economic future for Rhode Island.

While it may never be appropriate for URI to establish a goal of building, say, an aeronautical or astronautical research program, state economic policy makers and University leaders should reflect upon the folly of continued low research investment (leading to low research productivity) in fields that are important to maintaing a leading edge for the Rhode Island economy.

Benchmarks for Funding Research Infrastructure

Funding Buildings, Laboratories, and Fixed Equipment

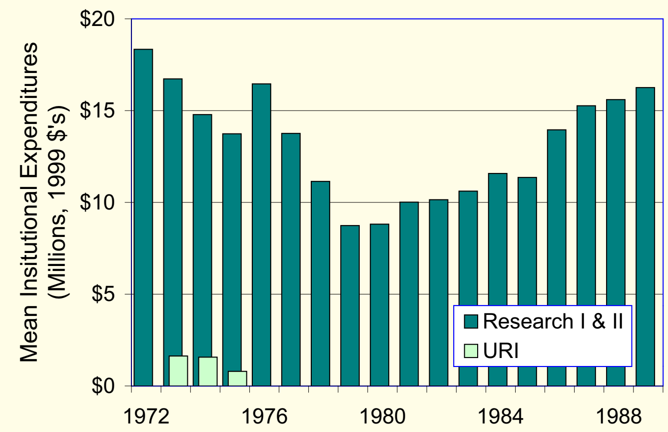
To understand Rhode Island's relative effort to build its economy through University research, we also need to compare support for construction of new research space, renovation of outmoded research buildings and laboratories, and replacement or upgrades for equipment.

Maintaining a leading edge in research and graduate education in the sciences and engineering requires constant upgrading of buildings, laboratories, and major items of equipment—collectively, "infrastructure." Major ("fixed") items of equipment—instruments over $500[20], with life expectancies of more than two years—include such things as electron microscopes, robotic gene sequencers, and major analytic machines. Even expensive and sophisticated instruments may become outdated in 3-10 years in areas of science where technology is advancing most rapidly. State-of-the-art laboratories may require renovation after 15-20 years, and even entire buildings may prove inadequate only 30 or 40 years after they are built, requiring renovation or replacement.

The research operations expenditures reported in the previous section do not include spending on infrastructure. NSF conducts separate surveys of workspace (i.e., buildings and laboratories used for scientific and engineering research) and fixed equipment. These data are gathered annually from research-performing institutions (i.e., those with more than $50,000 in research operations expenditures in the most recent NSF survey). Published survey results, on-line data, and methodology are available through the NSF web site, www.nsf.gov[21].

Buildings and Laboratories: Space for Research. NSF publishes reports on facilities every two years, summarizing the quantity and quality of research space for various fields of science and engineering. The most recent publication is "Scientific and Engineering Research Facilities at Colleges and Universities, 1998," which was published in

Prior to 1989, NSF published information on total capital expenditures—collectively, fixed or expensive movable equipment, construction costs (site work, architect fees, building, etc.), and major equipment[15]. From 1972 to 1989, URI's total reported capital expenditures ($1.3 million, 89% from federal sources) for research and development were 1.7% of the institutional average of the Carnegie Research I & II Universities.



In the 1970s and 80s, URI reported significantly lower capital expenditures than the average research university.

October 2000[22]. (Preliminary survey data from 1999 are available online.) The 1998 survey covered 660 colleges and universities. Fifty-seven percent (378) were doctorate-granting, including the "top 100" and 278 "other" institutions, based on R&D expenditures[23].

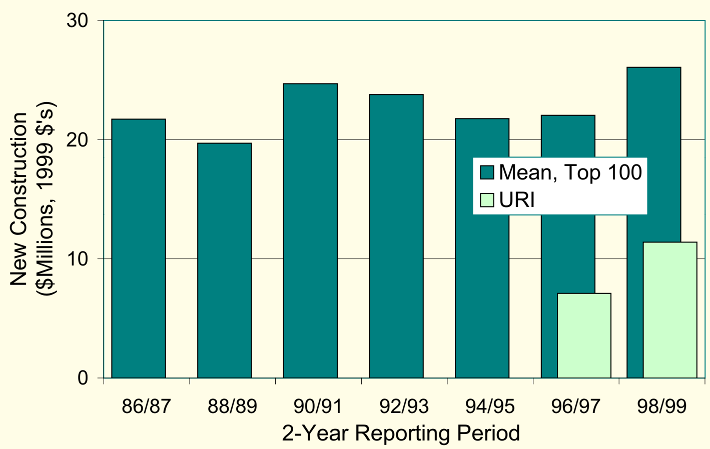
In the overview to the 1998 report, NSF outlines the critical research space issues for the nation. These translate directly into issues for Rhode Island and URI policy makers.

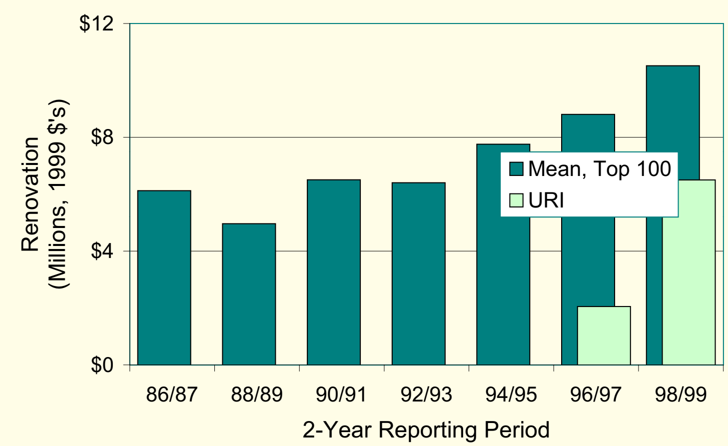
- *How much space is there for conducting S&E (science and engineering) research?*
- *Is this enough space to meet the Nation's S&E research needs?*
- *What is the condition of this space?*
- *How much new S&E space needs to be constructed? How much of the existing S&E space needs repair or renovation?*
- *How much construction and repair/renovation is taking place and what does it cost?*
- *How do colleges, universities, and biomedical institutions fund these capital projects?*
- *How has the situation changed over the past decade?*

How does the amount of research space at URI compare to other doctorate-granting universities and the top 100?

The 378 doctorate-granting colleges and universities in the 1998 survey accounted for 416 (85%) of the estimated 488 million square feet of *instructional and research* space in *all* academic fields, and 261 (91%) of the 286 million square feet of *instructional and research* space in *science and engineering* fields **(Table 5)**[24]. The top 100 accounted for 71% of research space (and 80.7% of all research expenditures).

The number of square feet of space allocated to research at URI, 237,600 (**Table 5**, last column), is 56% of the average for all doctorate-





In the late 1980s and 1990s, investment in new S&E construction continued at a steady rate and renovation of existing space increased for the top 100 research universities, which accounted for 81% of academic R&D expenditures and 71% of research space by 1999. URI data is only for 1996/97 (actual) and 1998/99 (estimated for NSF, 1998).[22]

granting institutions, and 24% of the top 100. The percentage of available instructional and research space allocated to research at URI (38%) is 67% of the average percentage of doctorate-granting institutions and 60% of the percentage of the top 100.

How does distribution of research space among science and engineering fields at URI compare to the national pattern?

Table 6 compares amounts and relative percentages of research space across major fields of science for all research universities, top 100 and other doctorate-granting research universities, non doctorate-granting research universities, and URI. Relative distribution of space allocated to environmental sciences (Earth, Atmospheric, and Ocean Sciences) is proportionally higher at URI, as are relative amounts for psychology (includes the cancer prevention research center), engineering, and other (mostly human development) sciences. Conversely, smaller proportions of research space are devoted to physical sciences, mathematics and computer sciences, biological and medical sciences, and the remaining social sciences. The difference in relative amounts of space for the biological sciences (22% nationally versus 4% at URI) stands out.

Is the amount of space in each field of science adequate to meet current needs?

NSF's 1998 facilities report[22] indicated that for all fields of science surveyed except mathematics, at least half of surveyed institutions reported inadequate amounts of space for research. Nationally, space for academic science and engineering research space increased 28% between 1988 and 1998. The same surveys indicate that across all science and engineering fields, only 39% of existing research facilities are considered "suitable for use in most scientifically sophisticated research."

The need for additional space and the assessment of the condition of space is determined by a survey distributed to University officials and to academic department chairs. As such, it is highly subjective and in

Table 5. Instructional and research (I&R) space (millions of net assignable square feet[25]) for research-performing institutions, for all academic research and for science and engineering (S&E) research, by institution type, 1998.

		—Instructional and Research—		—Research Only—		Mean Research
	Number of Institutions	Space in all Academic Fields	Space in S&E Fields	Space in S&E Fields	% of I&R Space	Sq. Ft. (1000's) per Institution
Total	660	488	286	143	50.0	217
Doctorate-granting	378	416	261	136	52.1	360
Top 100	100	252	177	101	57.1	1,010
Other	278	164	84	35	41.7	126
Nondoctorate-granting	282	72	25	7	28.0	25
URI (Sq. Ft. in 1000's):	1	n/a	620	238	38.3	238

Table 6. Amount of science and engineering research space (1000s of net assignable square feet), and percentage distribution by field of science, by institution type. National data is 1998. URI data is 1999[26].

	—Doctorate-granting—									
	Total		Top 100		Other		Nondoctorate		URI	
Field of Science	NASF	%	NASF	%	NASF	%	NASF	%	NASF	%
Engineering	22,833	15.9%	16,192	16.0%	6,312	18.2%	329	4.4%	51.8	21.8%
Physical sciences	18,191	12.7%	11,205	11.1%	5,200	15.0%	1,786	24.1%	8.4	3.5%
Environmental sciences	7,524	5.3%	5,416	5.3%	1,676	4.8%	431	5.8%	77.9	32.8%
Mathematical sciences	889	0.6%	460	0.5%	286	0.8%	144	1.9%	0.3	0.1%
Computer sciences	2,018	1.4%	1,381	1.4%	442	1.3%	195	2.6%	0.9	0.4%
Agricultural sciences	24,607	17.2%	20,141	19.9%	3,155	9.1%	1,310	17.7%	59.3	25.0%
Biological sciences	31,067	21.7%	20,797	20.5%	8,475	24.5%	1,795	24.2%	13.9	5.8%
Medical sciences	25,129	17.5%	19,339	19.1%	5,609	16.2%	180	2.4%	12.4	5.2%
Psychology	3,360	2.3%	1,841	1.8%	1,056	3.1%	463	6.2%	10.9	4.6%
Social sciences	4,620	3.2%	2,912	2.9%	1,185	3.4%	524	7.1%	1.9	0.8%
Other sciences, n.e.c.	3,050	2.1%	1,588	1.6%	1,210	3.5%	252	3.4%	0	0%
Total	143,288		101,272		34,606		7,409		237.6	
% of National Total		100.0%		70.7%		24.2%		5.2%		0.13%

need of, as NSF cautions, "careful interpretation." URI survey data is developed by the URI Research Office.

Table 7 summarizes URI space data from 1999, with comparisons from national data for all institutions with research space in the respective fields[26]. Relatively high URI space usage in agriculture includes high square footage of barns, old farm buildings, greenhouses, etc., assigned to the Agricultural Experiment Station and Plant Science and Animal Science departments): despite a large space inventory, the agricultural sciences (as well as the biological sciences in general) suffer from an inventory of buildings and laboratories that are 30-90 years old and in need of renovation or replacement before these sciences can fully engage in state-of-the-art technology-driven research.

The determination of adequacy is also affected by the condition of space. Estimating that 50-70% of existing URI space for agriculture, biological science, or medical sciences is suitable for "the most scientifically competitive research in the field" patently overstates the quality of the space inventory in these fields (see next item).

How much new S&E space needs to be constructed? How much existing S&E space needs repair or renovation?

In the 1990s four buildings with research laboratories (the Kirk Applied Engineering Lab, the Cancer Prevention Research Center, The Kingston Campus Coastal Institute Building, and the Center for Atmospheric Chemistry Studies), were constructed at URI, adding to space inventory for atmospheric sciences, agricultural sciences, social sciences, and industrial engineering. Most science fields at URI have seen no new construction nor renovation of R&D facilities in 30+ years. URI's *total* expenditures for construction and renovation of research space since 1970 (figures on pages 12 and 13) are under the ~$18 million *annual* capital expenditure average of top 100 research Universities.

1998 URI estimates of new space needed—85,000 square feet (**Table 6)**—may understate actual need. After these estimates were made, for example, the Environmental Biotechnology Initiative, a faculty-driven effort, recommended construction of new core facilities in genomics, transgenics, imaging, and informatics, with an estimate of 50-85,000 square feet needed for plant and animal biotechnology laboratories. A bond issue to finance the EBI facilities was proposed to

Table 7. Amount of URI research space (Table 6) per Expended Research Dollar (Table 4) by field, estimated additional space needed, and current condition of S&E space for URI/nationally, 1999.

Field of Science	Sq. Ft. (x1000) Needed (% incr.)	Condition* A	B	C	D
Engineering	0 (0)	20/43	50/35	30/17	/5
Physical sciences	10 (111)	20/41	30/36	30/19	20/5
Environmental sciences	10 (15)	50/39	30/34	5/21	15/6
Mathematical sciences	0 (0)	50/52	50/33	/12	/3
Computer sciences	5 (610)	50/43	5/35	/15	/7
Agricultural sciences	20 (71)	60/33	25/34	13/23	2/10
Biological sciences	10 (278)	70/41	20/30	10/22	/6
Medical sciences	10 (89)	50/31	50/43	/20	/6
Psychology	5 (85)	80/39	20/39	/19	/4
Social sciences	5 (474)	60/43	20/39	10/15	10/3
Other sciences	0 (0)	50/70	30/19	20/9	/22
Total	85 (44)				

* Condition: % of Total (Table 6) in following categories:

A Suitable for the most scientifically competitive research in the field;

B Effective for most levels of research in the field, but may need limited repair/renovation;

C Requires major renovation to be used effectively;

D Requires replacement.

the Board of Governors for inclusion on the 2002 ballot. An additional 10,000 square feet of greenhouse space for transgenic plants and 10,000 square feet to replace an agronomy farm field house are also needed.

Planned repair and renovation projects and unfunded space needs, from the 1998 URI estimates, are listed in **Table 8**[27]. These include $55 million for renovations and $0.6 million for new construction. The latter does not reflect more recent discussions of a new biotechnology building, with an approximate cost upwards of $50 million.

The space planning process at URI is driven by internal prioritization of academic needs, based on the desires of academic department chairs and college deans. Priorities reflect the University's commitment to undergraduate students. Current projects include renovation of Green Hall—to centralize the registrar and bursar—and renovation of Ballentine Hall to replace 16 classrooms plus offices for the College of Business. Renovation of Lippitt and Independence Halls also relate primarily to needs for classroom and office upgrades. The renovation of Ranger Hall, given bond approval in 1996, was intended to renovate a building used primarily for teaching: a suggestion to instead used Ranger for the Environmental Biotechnology Initiative was not proposed until 1999. Woodward Hall—a mixture of offices (50%), classrooms (10%), and laboratories (40%)—was renovated in 1996 due to asbestos abatement.

There is no clear relation of URI space planning processes to the specific enhancement of University infrastructure to better relate the University to the State's economy—for example, to build research space for computer sciences in response to economic needs for information technology. There are no plans to build on-or-near-campus centers for the development of industrial research collaborations or for commercialization of research products from such collaborations. This subject is dealt with further, below.

How are research capital projects funded? Nationally, in 1996/97 public institutions funded S&E research facility repairs and renovation from either state and local (49%) or institutional funds (27%). URI funded 1996/97 repair and renovation 98% from state funds (institutional funds made up the last 2%) (**Table 9**).

Nationally, new construction (>$100,000 per project) depended on state (47%) and institutional funds (43%, including 13% private, 13% institutional, and 13% tax-exempt bonds). URI funded 1996/97 construction with 13% federal and 79% institutional funds (including private 14%, institutional 8%, and bonds 56%). The accrual of debt service on bonds is a major financial burden on the University. The University may be able to offset some debt servicing through charges for facilities use (e.g., dormitory fees, convocation center ticket sales, etc.), but this is unlikely for capital improvements for research facilities.

How has the situation changed over the past decade? Nationally, the amount of S&E academic research space increased 28% over the past decade, but the amount of space requiring renovation or replacement has increased in all fields but mathematics, as the nation's exponential growth in science facilities in the 1960s begins to show its age. Five fields have seen an increase of over 100% in the amount of space needing major renovation or replacement, including social sciences (147% increase), medical sciences outside medical schools (125%), environmental sciences (earth, atmospheric, and ocean sciences 111%), agricultural sciences (108%) and biological sciences outside medical schools (100%)[22].

URI's buildings and laboratories are also showing their age. Expenditures in 1996/97 (**Table 7**) for repair and renovation and corrected estimates for 1998/99 (**Table 8**[23]) averaged $1 million annually. There remain ~$55.5 million in needed repairs and renovation (**Table 8**). URI's S&E R&D facilities have grown with the four projects noted above, completed between 1996 and 2001—for use in atmospheric sciences, natural resources management and natural resources economics, social sciences, and industrial engineering—with no growth in other fields.

Equipment: Tools for Research. NSF stopped reporting individual institutional capital expenditure data (e.g., figure on page 12) after 1989. Construction and repair and renovation data were replaced by the "Scientific and Engineering Research Facilities at Colleges and Universities" survey and publication series, discussed above. Individual institutional data on expenditures for fixed equipment, however, continue to be reported. Data are available on line for fiscal years 1981-99 as part of the "Survey of Scientific and Engineering Expen-

Table 8. URI 1998 estimates of planned S&E construction and repair/renovation projects over $100,000 and needed but unfunded projects, as net assignable square feet (NASF) with estimated cost ($1000s), by field.

	—Planned Projects Over $100,000—				—Cost of Needed but Unfunded Space—			
	New Construction		Repair/Renovation		In a Plan		Not in a Plan	
Field of Science	NASF	Cost	NASF	Cost	Construct	Renovate	Construct	Renovate
Engineering			5,000	$200	$200	$5,000		
Physical sciences			5,000	$200	$50	$9,000		
Environmental sciences	5,000	$3,000			$50	$2,000		
Mathematical sciences								
Computer sciences							$80	$10,000
Agricultural sciences	50,000	$7,000						
Biological sciences			n/a	$4,600	$60	$10,000	$60	$14,000
Medical sciences					$60	$3,000		
Psychology	10,000	$1,400						
Social sciences			13,000	$1,500	$13	$2,500		
Other sciences.								
Total	65,000	$11,400	23,000	$6,500	$433	$31,500	$140	$24,000

Table 9. Sources of funds for the construction and repair/renovation of scientific and engineering research facilities at **public** institutions and URI[26], for the two-year period, 1996-97[28].

	National Total			Top 100		URI		
	$Millions (1999)	per capita	% of total	$Millions (1999)	% of total	$1000's (1999)	per capita	% of total
Repair/Renovation								
Federal	**$74**	**$0.263**	**10.76%**	**$30**	**7.20%**	**$0**	**$0.000**	**0.00%**
State/local	**$337**	**$1.198**	**49.03%**	**$185**	**44.67%**	**$2,056**	**$1.962**	**97.56%**
Internal	**$276**	**$0.982**	**40.21%**	**$199**	**48.14%**	**$51**	**$0.049**	**2.44%**
Private	*$39*	*$0.139*	*5.68%*	*$35*	*8.44%*	*$0*	*$0.000*	*0.00%*
Institutional	*$185*	*$0.657*	*26.91%*	*$137*	*33.00%*	*$51*	*$0.049*	*2.44%*
Tax-exempt bonds	*$26*	*$0.091*	*3.74%*	*$12*	*2.98%*	*$0*	*$0.000*	*0.00%*
Other debt	*$0*	*$0.000*	*0.00%*	*$0*	*0.00%*	*$0*	*$0.000*	*0.00%*
Other sources	*$27*	*$0.095*	*3.89%*	*$15*	*3.72%*	*$0*	*$0.000*	*0.00%*
Total	**$688**	**$2.443**	**100.00%**	**$414.16**	**100.00%**	**$2,107**	**$2.011**	**100.00%**
New Construction > $100,000								
Federal	**$207**	**$0.734**	**10.11%**	**$133**	**9.60%**	**$925**	**$0.883**	**12.68%**
State/local	**$966**	**$3.433**	**47.28%**	**$672**	**48.66%**	**$617**	**$0.588**	**8.45%**
Internal	**$870**	**$3.093**	**42.61%**	**$577**	**41.74%**	**$5,755**	**$5.492**	**78.87%**
Private	*$274*	*$0.975*	*13.43%*	*$195*	*14.14%*	*$1,028*	*$0.981*	*14.08%*
Institutional	*$256*	*$0.909*	*12.53%*	*$219*	*15.85%*	*$617*	*$0.588*	*8.45%*
Tax-exempt bonds	*$267*	*$0.949*	*13.08%*	*$140*	*10.12%*	*$4,111*	*$3.923*	*56.34%*
Other debt	*$55*	*$0.197*	*2.72%*	*$22*	*1.56%*	*$0*	*$0.000*	*0.00%*
Other sources	*$17*	*$0.062*	*0.86%*	*$1*	*0.07%*	*$0*	*$0.000*	*0.00%*
Total	**$2,043**	**$7.260**	**100.00%**	**$1,381.23**	**100.00%**	**$7,297**	**$6.962**	**100.00%**

ditures at Universities and Colleges," under the data source "Current Fund Research Equipment Expenditures," through WebCaspar[9] and annual reports[29].

Statewise comparisons: *How does Rhode Island compare in spending for University research equipment?* Expenditure data from the Current Fund Research Equipment Expenditures survey from 1997 to 1999 (in 1999 $'s) were used for comparison. Mean and per capita total, federal, and non-federal (includes state, institutional, private, and industry) research equipment expenditures for the 133 comparison institutions and state totals are listed in **Appendix Table 3**.

Adjusting each state's *total* spending on research equipment to per capita (**Table 10**), Rhode Island ranked 20th during 1997-99. 84% of RI expenditures were from federal sources, compared to 57% nationally. Rhode Island's per capita *state* expenditures ($0.83) were 43% of the national average, ranking it 45th.

<u>Benchmarks for Funding University Research Infrastructure</u>. Academic research infrastructure provides the workplaces and tools used by scientists, technical support staff, and students. Having invested little in buildings, laboratories, or equipment for three decades, URI needs State help with new buildings, accelerated renovation of old buldings and laboratories, and the acquisition of state-of-the-art fixed equipment. Without investment, URI may not be able to remain competitive in oceanography and will remain at a competitive disadvantage in the remaining sciences and engineering.

It would be unwise to base benchmarks for state funding for infrastructure on on a goal of attaining a national average per capita level of investment. Such a goal would never allow URI to catch up:

• Attaining average per capita state support for new construction of science and engineering facilities would require a 4% increase over the level of 1996-97, or $0.13 per capita (total $0.14 million) annually.

• Attaining average per capita state support to renovate S&E research space would require 6% more than in 1996-97, an additional renovation effort of $0.06 per capita (total $0.06 million) annually.

These goals would create an annual renovation budget of $1.1 million and a construction budget of $3.3 million. *Although these figures are greater than the current projections, they would not suffice to meet needs*. The $55 million backlog of repairs and needed renovation is too great to be met with a budget of $1.1 million annually. A construction budget of $3.3 million annually would permit less than one small new science or engineering building every decade, and certainly would not permit projects such as the faculty's contemplated new biotechnology building: A budget of $3.3 million would not service debt on such a building. Clearly, benchmarks for renovation and construction based on a goal of national average will never suffice to overcome URI's backlog and failure to build over the past 30 years.

If Rhode Island desires a public university with a research capacity sufficient to help the State's economy, it needs to eliminate the research infrastructure renovation backlog and to build new state-of-the-art research laboratories. At a minimum, the **benchmark should be set at a doubling of the 1996/97 average renovation and construction figures (i.e., to $2.1 and $6.4 million annually).** This would still only approximate the annual mean figures for the top 100 institutions (i.e., $1.9 and $6.3 million of state and institutional funds annually, from **Table 9**)[30]. The benchmark might be lowered by ~10% if the State would develop an alternative to heavy reliance on debt-bearing bonds as its primary method of funding new construction (e.g., 56% of funding for 1996-97 construction, **Table 9**), or if the State would assume responsibility for debt service on those bonds (i.e., not pass it on to the University). These figures would conceivably permit a more realistic schedule for renovation (at least, one that matches the pace of deterioration) and construction of a major new facility more often than once each decade: this should be taken as a very minimum for an investment target.

• Attaining mean (of 50 states) per capita level of state support for fixed research equipment (based on **Table 10** and in 1999 dollars) would require a 145% increase, $1.20 per capita (total $1.3 million) annually[31].

The total benchmark for S&E infrastructure—comprising construction, renovation, and fixed equipment—would thus be at a minimum ~$10 million annually (60% for construction, 20% for renovation, and 20% for equipment).

Table 11 summarizes operational and infrastructure funding benchmarks. The increase for S&E research (~$23.2 million) would require

Table 10. Per capita total and state expenditures for S&E university research equipment, ranks, and % of total from state, 1997-99, in 1999 $s.

	Total	Rank	State	Rank	% State
Alabama	$4.47	29	$1.60	30	35.85%
Alaska	$9.87	3	$5.23	2	52.96%
Arizona	$4.13	30	$1.66	28	40.27%
Arkansas	$2.33	45	$1.20	38	51.55%
California	$4.62	27	$1.34	33	28.92%
Colorado	$5.02	19	$1.51	31	30.16%
Connecticut	$4.64	24	$1.81	24	38.97%
Delaware	$8.70	5	$4.99	4	57.35%
Florida	$3.31	37	$1.31	35	39.46%
Georgia	$7.89	6	$5.02	3	63.57%
Hawaii	$7.18	7	$2.51	12	34.88%
Idaho	$2.64	41	$1.18	39	44.66%
Illinois	$5.63	8	$1.90	21	33.68%
Indiana	$4.69	23	$2.12	17	45.28%
Iowa	$5.10	16	$2.87	10	56.26%
Kansas	$5.14	13	$2.95	9	57.27%
Kentucky	$2.59	43	$1.31	34	50.74%
Louisiana	$5.18	12	$3.43	7	66.29%
Maine	$1.98	46	$0.60	47	30.31%
Maryland	$11.71	1	$5.70	1	48.72%
Massachusetts	$10.67	2	$2.97	8	27.80%
Michigan	$3.61	33	$1.74	27	48.27%
Minnesota	$2.93	40	$1.12	41	38.15%
Mississippi	$3.44	36	$1.12	42	32.52%
Missouri	$4.63	26	$1.82	23	39.43%
Montana	$1.76	48	$0.42	49	23.95%
Nebraska	$5.08	17	$3.73	6	73.44%
Nevada	$1.55	50	$0.72	46	46.80%
New Hampshire	$4.78	21	$1.23	37	25.72%
New Jersey	$2.55	44	$1.01	43	39.46%
New Mexico	$9.25	4	$2.22	16	23.97%
New York	$5.23	10	$1.92	19	36.81%
North Carolina	$5.04	18	$2.32	14	46.12%
North Dakota	$4.64	25	$1.75	26	37.68%
Ohio	$3.49	34	$2.08	18	59.67%
Oklahoma	$3.65	32	$2.29	15	62.80%
Oregon	$2.59	42	$0.41	50	15.71%
Pennsylvania	$4.71	22	$1.86	22	39.56%
Rhode Island	$5.02	20	$0.83	45	16.45%
South Carolina	$3.45	35	$1.80	25	52.18%
South Dakota	$1.86	47	$0.88	44	47.47%
Tennessee	$3.02	39	$1.24	36	40.91%
Texas	$3.95	31	$1.91	20	48.45%
Utah	$5.22	11	$1.48	32	28.37%
Vermont	$4.58	28	$2.33	13	50.98%
Virginia	$3.03	38	$1.16	40	38.35%
Washington	$5.13	14	$1.66	29	32.40%
West Virginia	$1.57	49	$0.57	48	36.04%
Wisconsin	$5.60	9	$2.64	11	47.24%
Wyoming	$5.12	15	$3.74	5	73.14%
Means:	*$4.68*		*$2.02*		*42.74%*

Table 11. Summary of State (includes grants and public institutional funds) research operation and infrastructure funding benchmarks (see text for derivations). Dollars are based on mean operations or infrastructure expenditures (in 1999 $'s), derived from Tables 2, 9, and 10.

Target	**Benchmark State Funds, $s per capita**	**Benchmark State Annual Expenditure**	**Expenditure Increase (%)**
Operations	$25.66	$26.9 million	$21.6 million (412%)*
Infrastructure	$10.11	$10.6 million	$5.6 million (112%)
Construction	*$6.08*	*$6.4 million*	*$3.2 million (100%)***
Renovation	*$2.01*	*$2.1 million*	*$1.1 million (100%)***
Equipment	*$2.02*	*$2.1 million*	*$1.3 million (145%)**
Total	$35.77	$37.5 million	$27.2 million (264%)

** above mean 1997-1999 expenditures*

*** above 1996/1997 expenditures.*

Benchmarks for Targeting Research Investment

Developing a Strategy for Investing in University Research for Economic Development

In an entity as complex as a state university, myriad factors and perspectives affect an institution's view of itself and its chances of success as a research university. Important actors who will determine URI's research future—and, it is assumed, Rhode Island's economic future as well—include State Government leaders, the Board of Governors, URI's administrative officers and faculty, and multiple external supporters. These disparate individuals, with divergent perspectives, must not only come together to address the fiscal shortcomings addressed in the preceding section: They must also link with State economic leaders to develop strategies for investment in University research that can lead to success, for both the University and the State.

The general dynamics of successful leading edge American Research Universities since World War II[32] must be applied to URI if it is to emerge into the top 100 or further (*see* Strategies for Innovation and Impact, below). Important precursors to this emergence include development of a consensus on approaches to strategic planning for research and a greater awareness of the value of focused science and engineering research centers, the subjects of this section. Another precursor to success may be the development of congruent technology commercialization and industrial collaborations through research and technology parks, the subject of the following section.

Approaches to Strategic Planning

Building from natural advantages. Before the State gives URI greater support for research, it will need plans that explain benefits from the investment. There are two perspectives from which to plan. A "Build from Strengths" approach focuses on assessment of fields in which the University possesses some natural advantages[33]—which then are viewed as primary targets for investment. URI Strategic Plans[34] recognize strengths in four areas which are to be favored for growth:

- Marine and the Environment
- Health
- Children, Families, and Communities
- Enterprise and Advanced Technology

Similarly, the Rhode Island Economic Policy Council based its Samuel Slater Technology Fund investments largely on existing university research capacities. The resulting Centers of Excellence then use these natural advantages to "foster industry-university collaborations, build and strengthen relationships among academic institutions, and develop industry clusters." The Slater Centers are:

- Biomedical Technology
- Design Innovation
- Environmental Biotechnology
- Interactive Technologies
- Advanced Manufacturing
- Ocean Technology

The build-from-strengths approach is thus oriented to existing academia and to the question, "What do our colleges and universities do best *now* that we can use to build a better state economy?"

Building toward future needs. There is also a need for a second planning approach that takes a broader perspective and a longer time frame. The long-term interests of the state suggest the importance of a "Build toward Needs" approach that focuses on the questions, "What is the future economy that we want? What do we need from our colleges and universities to build that economy? How can we best support academic research and teaching to build what we will need?"

Both approaches must acknowledge the proclivity of university faculty and academic departments to form their own academic priorities and corresponding research agendas. The three strongest determiners of academic research agendas are faculty curiosity, value of the research to professional advancement, and external grant opportunities. These may not suffice to drive scientists or engineers to work on the highest priority needs of the future State economy.

Financial opportunities may be used to persuade researchers and administrators that there are sufficient academic reasons to respond to a particular request for proposals. All researchers have ongoing needs to support graduate students and technical staff, and to acquire state-of-the-art equipment. A build-toward-needs approach could help meet researcher needs through an outcome-funding program.

Programmed Research. Research to promote economic development is "programmed research," directed by funding agencies which focus funds directly on specific goals. Although some agencies continue to fund curiosity-driven research (aka "basic"), an increasing portion of federal funding and virtually all industrial funding is for programmed research, usually for targeted outcomes that link academic research outputs (i.e., papers, technologies, inventions) to specific outcomes (practices, technologies) used by target audiences[35].

While a detailed national survey or local priority-setting analysis of programmed research opportunities is beyond the present scope, examples can serve to stimulate further discussion. For applied science and engineering, some of the best examples of focused research centers are listed in **Appendix Table 4.** These were chosen from the National Science Foundation Engineering Research Centers (ERC)[36], Industry/University Cooperative Research Centers (I/UCRC)[37], and Materials Research Science and Engineering Centers (MRSEC)[38] to illustrate leading edge research activities in the nations top universities. These centers were first established in the mid 1980s. It is significant that they are NSF Centers, developed by the lead federal champion of basic science! Their explicit purpose is to promote collaboration between universities and industry on interdisciplinary research on generic topics. Industry contributes about one-third of Center budgets. A few additional examples of state-supported centers[38] are also included.

Initial Investment Targets. The search for natural advantages upon which to build economically-oriented research programs leads to some obvious current strengths as starting points.

- The strength of the Graduate School of Oceanography's research campus (average over $20 million annually in grant awards), for example, suggest investments in **ocean technology**, including devices to monitor physical aspects of the ocean and technologies to detect pollution or other biotic measures of ocean health.
- Large number of biologists on the URI faculty support a conceptual plan for centralized facilities for **Environmental Biotechnology**[39].
- Engineering research programs (e.g., **surface and sensor technologies**) may also precipitate future URI research centers.

If Rhode Island adopts the benchmarks suggested above for funding research operations and infrastructure, it will certainly place a high priority on developing a core biotechnology facility[40].

New Priority-setting Mechanisms to link University Research to State Needs. The State and URI need a way to set priorities for large-magnitude investments such as the Environmental Biotechnology Initiative (i.e., centers that require both infrastructure and operation funds) and both need a consensus plan for the state economy that is based on investment in the R&D potentials of the public research University, along the lines of the examples in **Appendix Table 4**. State planners must recognize that major development at the University needs to fit the institution's aspirations and vision. University leaders must respond to State needs for an entrepreneurial science and engineering engine for its economy. Together the University and the State must come to concur on the State's future needs and appropriate investment priorities within the University to meet those needs.

For its part, the State will want to be assured that funding used to enhance research capacity will eventually connect to the economy. This can be accomplished through enhancement of University-affiliated technology development and commercialization programs. For its part, the University needs to see an enhanced research capacity as an essential part of the intellectual growth of the institution—leading toward a mature entrepreneurial learning culture in the sciences, engineering, and business. A closing section discusses these concerns further.

The University of Nebraska's new core biotechnology facilities may someday serve as a model for URI's Environmental Biotechnology Initiative.

Benchmarks for Linking Research to the Economy

Academic research benefits the economy as a source of scientific discoveries and technological inventions, and as a vehicle for training scientists and engineers. Benefits can be enhanced when universities link their research laboratories to the economy through **technology transfer**, **commercialization**, or engagement in campus-affiliated **research and technology parks**. These should be considered as means to better tie URI to the State economy.

Nearly all research universities have offices of **technology transfer** to promote patents on inventions or “intellectual properties” from university labs, and to sell or license patented technologies to companies, transferring a legal right to use, develop, or market products.

The Bayh-Dole Act of 1980 created a uniform policy for all federal agencies that fund academic research. It transferred to the universities the rights of ownership and the right to income generated through licensing. It also encouraged the issuing of licenses to small firms capable of bringing the invention to practical application. Bayh-Dole is intended to expedite the commercial use of inventions created with federal funds[(41)].

The FY1999 Licensing Survey of the Association of University Technology Managers[(42)] covered 190 U.S. and Canadian universities, teaching hospitals, research institutes, and patent commercialization companies. The Survey showed that at least 417 new products were introduced from 98 institutions in FY1999, including licenses for health care products, software, agricultural products, and research reagents and tools used by industry and universities for research, development, or commercial purposes. The licenses generated $40.9 billion in economic activity and supported 270,900 jobs, according to AUTM. 62% of the 3,914 new licenses were to companies with fewer than 500 employees, and 344 were to new companies created to develop and commercialize results from academic research, 82% of them in the state of the university that licensed the technology.

Beyond simply marketing rights to develop and sell the products of research, many universities are actively taking inventions into the marketplace through various forms of **commercialization**. The October 1999 National Workshop on Research Centers of Excellence, hosted in Newport RI by the RI Economic Policy Council, sampled 10 invited states, which shared their approaches to technology-based economic development. One thing that was clear from the conference was that although all participants were engaged in long-term efforts involving university-industry technology development and commercialization, there was a significant array of “typologies” in the organization of centers, including broad and narrow technology foci, and various approaches to promote and develop basic research at universities and to commercialize it.

A broader survey of university affiliated business incubators and research / technology parks makes it clear that there is a wide spectrum of approaches to commercialization. **Appendix Table 5** provides examples of commercialization efforts from our sample group.

The first **university-affiliated research / technology park** was established by Stanford in 1951. By 1975, there were only ten parks, but 25 more followed within the next decade. In the early 1980s only about one in four research parks was successful in attracting industries, yet universities continued to be drawn to hopes of increased interactions with industry based on university research. Research parks were viewed as one path toward that goal.

Appendix Table 5 presents a broad spectrum, with each institution unique in many ways. At one end of the spectrum are the very top research universities, including Berkeley, Harvard, UCLA, Cornell, Johns Hopkins, Minnesota, Stanford, Yale, MIT, Caltech, and Wisconsin, and perhaps a half dozen more. For the most part, these institutions are characterized by faculty and students at the highest levels of basic science and the forefronts of technology. The entrepreneurial abilities of these faculties and graduates are reflected throughout the US economy. Curiously, precise analyses of the economic impacts of these institutions are lacking, with the recent exception of a BankBoston study, “MIT: The Impact of Innovation,” which will be discussed briefly in the concluding section. Institutions like MIT affect the economy directly through myriad start-ups and mature large corporations founded by graduates or based on research spin-offs.

Some major Universities have research parks. Some parks are huge, with a mixture of large, often multinational, corporations, blended with smaller startups. The large parks of North Carolina's research triangle (**Duke, UNC Chapel Hill,** and **NCSU Raleigh)**, and the parks at the University of Arizona and Arizona State University are at once a product of research successes at those institutions, and a contributor to future strength. The involvement of collaborating research faculty, enrolled student apprentices, and graduated employees of the companies meets the goal of mutual benefits established when these parks were formed. U of A's park, established only in 1994, is particularly impressive for having full occupancy of its 1.8 million sq ft capacity, with plans for a 600,000 sq ft expansion.

Most research parks are considerably more modest, with fewer than 200 acres and often less than 100,000 sq ft of space. Many offer research and laboratory accommodations, usually with implied collaborations with the University, and usually for a limited duration, after which tenants are expected to "graduate" to more permanent company quarters. Most parks offer supportive business services, including help with legal, accounting, personnel and business planning services.


Utah Technology Park

At the lower end of the spectrum, Universities offer incubator services to support basic business functions of affiliated start-ups, increasing the odds that new companies will survive the early transition from academic research to the business world.

In considering incubators or technology / research parks to link URI research to the economy, Rhode Island is not starting totally cold. A decision to engage in technology-based economic development has already been made, and six Slater Technology Fund Centers of Excellence are already in place to serve as conduits to transport advanced research products into the marketplace. It remains to be seen, however, whether Rhode Island university research centers and university/industry collaborations can generate an adequate flow of new intellectual properties to adequately feed the Slater Centers.

The University currently feels significant real space pressures, aggravated by a large inventory of buildings now being taken off-line for renovation and repair. URI is also under severe management pressures caused by budget shortfalls and high turnover in critical upper management positions. With their focus on factors affecting undergraduate enrollments and tuition dollars, conversion of on-campus space into technology incubators is an unlikely priority for campus leaders.

To accelerate a research-based approach to building the economy, URI needs a research and development park. Substantial land holdings at the University could meet needs for future open space, natural and agricultural research areas, and athletic field expansions with sufficient land left for a modest (50-60 acre) research park. Development could take place on Plains Road, over an existing Superfund site, for example. The State and URI need to consider the mutual interests of such a project, and to seek support services to manage new infrastructure and to grow new university/industry collaborations.

Benchmark Strategies for Innovation and Impact

Conclusions: Strategic benchmarks?

Roger Geiger's **Research and Relevant Knowledge**[43] is an analysis of factors affecting American research universities since World War II. URI has a great deal to learn from the experiences of successful research Universities. Rhode Island's State University is not alone in its struggles to find adequate funding for its many missions, nor in its internal and surrounding philosophical heterogeneity about just what those missions should be and in what priority.

A fundamental understanding that can be taken from Geiger's book is that today's University of Rhode Island has yet to establish itself as a top research university. The University on Kingston Hill focuses on undergraduates and the liberal arts. It has comparatively modest (i.e., very modest relative to top 100 institutions) research presence in behavioral psychology, some fields of engineering, and environmental sciences. It also has a meaningful affiliation with a reputable oceanography research institute only a few miles away. The University thus does have a necessary set of "natural advantages" in its faculty, programs, and setting from which it can build to eventual national prominence and research excellence. Oceanography, environmental biotechnology, some aspects of electrical or materials engineering, and elements of its social sciences (particularly those concerned with family and youth development issues) provide adequate starting points for growth, and there are potentially other kernels about which significant organized research units could be formed.

What is needed to elevate URI's standing among the nation's research universities is congruent with what is needed to make it a major actor in shaping the future Rhode Island economy. All public universities that have made major advances as research universities in the second half of the 20th century had several traits in common. They all began with vigorous commitments to higher standings as research institutions. They all had characteristically strong leadership at all levels of the institution, and in particular a determined President or presidentially-supported Provost who pursued that commitment to raise the institution to a higher plane. Most had strong backing from state government (i.e., public universities), the federal government, or industry. There was also usually an element of good luck or fortunate timing.

Reinvigorating URI as a research university strategically targeted to play a major role in State economic development must begin with affirmation by faculty and administration that the University is committed to a vibrant and robust research mission. That affirmation needs to be rooted by the establishment of realistic quantitative goals for its research mission, including aspirations to have organized research units (i.e., multi-department or multidisciplinary amalgams of researchers organized to support common research programs) or academic departments recognized as being among top research units nationally. The University also needs to set a goal to gradually increase its overall standing among research universities. Certainly, a goal of, say, doubling external funding—necessary to reach the top 100 in NSF's research expenditures ranking—will require determined commitment and leadership at all levels.

In 1997, BankBoston analyzed the impact of one of the Universities that was most prominent in Geiger's book, the Massachusetts Institute of Technology. "MIT: The Impact of Innovation[44]" measured the national job creation of this single research university, and in the process developed fascinating insight into why MIT alumni were able to make major contributions to the local and national economies. The study itself can serve as an intellectual benchmark for URI, setting for a clear intellectual standard for a new culture of entrepreneurial learning.

In reading the BankBoston study, it is initially difficult not to focus on the sheer impact of the nearly 4000 companies started by MIT graduates. In total, these companies employ 1.1 million people and had annual world sales of $232 billion, equivalent to the 24th largest national economy in the world. It is also impossible not to be impressed by the roster of large companies—now employing over 10,000 people each—founded by MIT graduates. These include Hewlett-Packard, Rockwell International, Raytheon, McDonnell Douglas, Digital Equipment, Texas Instruments, Campbell Soup, Intel, and Gillette.

What is more important for URI in both the Geiger and BankBoston studies is to recognize that the essential culture of the very top research universities is itself the primary reason that they are so relevant to the development of local economies. MIT and the other great research universities have a learning culture that instill an entrepreneurial spirit in graduates. Students come to realize, through exposures to great professors and top fellow students, a sense of critical humility (vital to CEO's who must learn to listen to customers and to respect the opinions of their employees). At the same time, completion of an MIT education instills confidence that bright people working together can solve problems. Hands-on approaches, encouraging solutions to real-world problems—brought in by faculty from their real-world industrial engagements—are combined with education that instills knowledge of the state of the art in the field of study.

In its academic and research endeavors in science, engineering, and business, URI needs to expand upon its commitment to a new culture for learning by developing and expanded commitment to the scientific, technical, and entrepreneurial side of that culture. Growth of economically-focused research centers of excellence is needed to balance the curiosity-driven research of individual scholars. Greater engagement with business and technology leaders outside of the University, made possible through research collaboration and technical exchanges in a new campus-affiliated research park, is needed to develop leading edge training opportunities.

At the same time, such exchanges can provide invaluable feedback on the quality of URI graduates—and their value to the economy as inventors, high-technology employees, and entrepreneurs. University academicians in the sciences, engineering, and business could profit from immediate feedback, to adjust the technical components of their curricula, forcing constant attention on the state-of-the-art relevancy of URI's applied science and technical training. Attention to feedback would provide one of URI's most valuable hallmarks of quality, and perhaps its strongest future marketing tool.

Rhode Island and its public research university cannot afford to be complacent about the current state of research and the economic relevance of URI, nor can URI ignore the need to anticipate future State economic needs or URI's role in meeting them. At the very least, everyone concerned with URI's future needs to be mindful of the relative state of our commitments to higher education and to economically targeted research investment, and of our clear need to do better.