

# A CLOSER LOOK AT SOME ALTERNATIVES TO SITKA SPRUCE IN AIRCRAFT CONSTRUCTION

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**S**ITKA SPRUCE (*Picea sitchensis*) has become so popular and common in wooden components of airplane construction that builders tend to believe it is the only acceptable material. Certainly, species native to North America, and more suitable, are either of limited supply or non-existent. However, there are a number of acceptable species available, and at considerably lower cost. Sitka spruce is rated low in durability, as are most of these other trees, and all should be treated with preservatives. Perhaps Sitka spruce is so popular because it is apparently the only wood that is singled out for "aircraft" inspecting and grading. Agreed; it is strong for its weight, soft and workable, and for the foreseeable future, in good supply.

Its natural habitat extends from Kodiak Island and Cook Inlet (southeastern Alaska) south along the Pacific coast to northern California. Logging has depleted aircraft-grade spruce in Washington, Oregon and California, even though in past years stands in Oregon and Washington contained some of the most splendid trees of record. Now only occasional trees bear witness of the past. Reforestation and management is programmed to supplying the paper-pulp industry or 50 to 75 year-old sawtimber which would contain too many knots for aircraft use. Hence, our reliable supply for aircraft use must come from British Columbia and Alaska. There are seven or eight spruce species native to the United States and Canada. Wood anatomy studies of conifers (cone-bearing trees) show little if any differences in quality and strength among species of a given genus, such as spruces and firs. Where problems arise is in availability of straight, clear and flawless timber in large enough pieces for our use. The common spruce of the Cascade and Rocky Mountains, Engelmann spruce (*Picea engelmannii*), serves well when one can find logs of proper quality. Some research people maintain that under a microscope it is impossible to separate by species, wood specimens from our native spruces, as well as among the firs. Other American spruces are: white spruce (*P. glauca*), black spruce (*P. mariana*), blue spruce (*P. pungens*), red spruce (*P. rubens*), and Brewer weeping spruce (*P. breweriana*).

## A REVIEW OF ALTERNATIVES

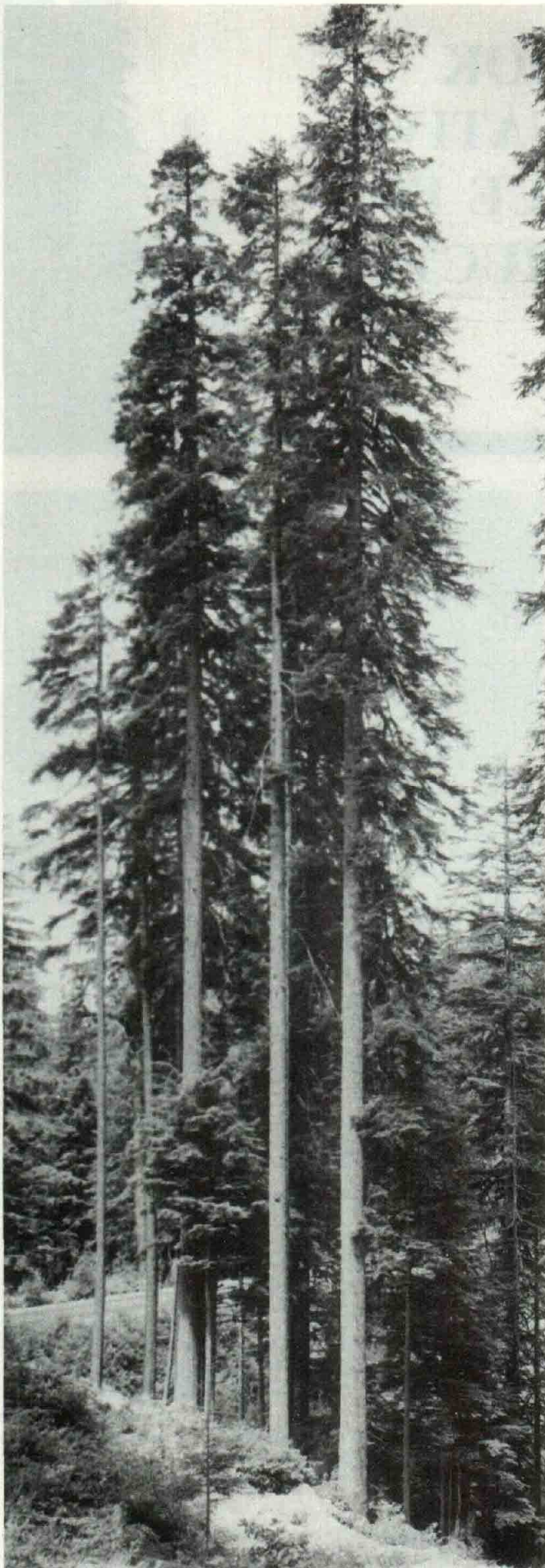
DOUGLAS FIR (*Pseudotsuga menziesii*), (formerly *P. taxifolia*) is actually **not** a fir, that is, not a "true" fir. Firs are of the genus *Abies*, while Douglas fir is of the genus *Pseudotsuga* or "false-hemlock." The wood fibers differ from the "true" firs by containing resin cells (or ducts) giving it a certain durability factor. This wood is stronger but heavier than either the spruces or firs, but can vary in hardness, density, and especially in weight, to the extent that aircraft material must be carefully selected.



(Photo by E. L. Parker)

**FIGURE 1: NOBLE FIR (*Abies procera*)** the largest of American firs, has a very high form factor yielding excellent sawtimber; Cascade Mountains of southern Oregon near Mt. McGlaughlin.

The best Douglas fir comes from northerly Pacific Slope stands, even though it is native to all States of the continental divide and westward, as well as northern Mexico and southwestern Canada. Fine-grained old-growth wood, with thin summer-wood (the rings or "grain") and thicker spring-wood (the lighter-colored area between the rings)



(Photo by O. V. Matthews)

**FIGURE II: PACIFIC SILVER FIR (*Abies amabilis*) displays its excellent form in this northwest Oregon forest in Clatsop County.**

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is softer, best to work, and usually lighter in weight. Since old-growth logs are usually peeled into plywood veneer, good material is increasingly difficult to find. Still, this is undoubtedly the most common "substitute" for Sitka spruce. A big percentage of old-growth Douglas fir is harvested from U. S. Forest Service and Bureau of Land Management reserves. These supplies are expected to last another 50 to 75 years; well into the 21st century. One drawback in Douglas fir is the occasional appearance of hidden pitch pockets which may show up only during manufacture.

**PORT ORFORD** (white) cedar (*Chamaecyparis lawsoniana*), is also known by horticulturists as "Lawson's cypress." Actually, there are no "true" cedars native to this hemisphere (of the genus *Cedrus*). Many American junipers, cypresses or arborvitae are called "cedars" because of certain botanical similarities. Port Orford cedar is one of three native species of *Chamaecyparis* (or "ground cypress") in North America, and if it were not such a rare tree, would be my choice for airplane construction. Its very limited habitat is extreme southwestern Oregon and adjacent northwestern California, confined mainly to an area from protected coastal lowlands inland 30 or 40 miles in canyons and ravines where moisture is abundant. Once more plentiful, it was popular for wooden boats, battery-plate separators, venetian blinds and arrow shafts. This wood is of a light straw-color, straight and fine-grained, strong for its weight (exceeding Sitka spruce) and extremely durable. Its former popularity for venetian blinds bears out another feature; its resistance to warping. Some builders have been led to believe the wood is too brittle and that its natural preservative "oils" resist proper gluing. Such is absolutely not the case. Anyone who can obtain this wood has the very best. In fact, one would really not need to varnish the wood except to perhaps enhance keeping it clean and dry. Very old pieces of Port Orford cedar, when sawed or sanded, quickly emit the pleasant and uniquely aromatic odor of the species. In recent years, Japan has purchased nearly all harvested Port Orford cedar, and it brings the highest price of all western conifers, including redwood (*Sequoia*). Its limited availability is further threatened by a root-rotting fungus now attacking some of the remaining stands.

**ALASKA YELLOW CEDAR** (*Chamaecyparis nootkatensis*), a close relative, is more abundant and found mainly in the Pacific Coast region from southeastern Alaska southeast to western British Columbia, western Washington and Cascade Mountains in Oregon (higher elevations). This "cedar" is also strong and decay-resistant, but a little darker in color and heavier than Port Orford cedar, and a favorite of woodcarvers.

**ATLANTIC WHITE CEDAR** (*Chamaecyparis thyoides*) is the third native "ground cypress," but a small tree, confined chiefly to the coastal plains from southern Maine to northern Florida, west to Mississippi. Regrettably, I am not familiar with the wood, but suspect that because of its rarity and small size, would not be a suitable source for our use.

**WESTERN HEMLOCK** (*Tsuga heterophylla*) is another Pacific Slope native, from southern Alaska (Kenai Peninsula) south to northwestern California. This wood is very strong, workable, and has been popular for flooring, furniture, ladder stock, dimensional lumber, paneling and occasional aircraft construction; as durable as spruce, but normally has a dense grain of thicker "rings" and thusly heavier.

Another less abundant western hemlock of good quality is mountain hemlock (*Tsuga mertensiana*) of high timberline regions from the Sierra Mountains north to southern Alaska, and east to southeastern British Columbia, western Montana, northern Idaho, and northeastern Oregon.

Our other two hemlocks are eastern hemlock (*Tsuga canadensis*), of the eastern United States and adjacent southern Canada, south to the mountains of Georgia and northern Alabama; and Carolina hemlock (*Tsuga caroliniana*) from the Appalachian Mountains of Virginia south to northern Georgia.

### THE PINES (*Pinus*)

Of the many American pines, few offer qualities for our use. Most of adequate strength are either overly resinous (pitchy), heavy, or both. Of our three commercial white pines; western white pine (*Pinus monticola*), sugar pine (*P. lambertiana*), and eastern white pine (*P. strobus*), only the latter has a strength rating possibly adequate to aircraft use.

**RED PINE** (*Pinus resinosa*) of the north eastern United States and adjacent Canada rates with Douglas fir in both weight and strength. The builder should be aware that among the more resinous pines, though natural decay-resistance properties may be present, much lumber tends to warp and shrink excessively. The softer species, such as sugar pine, western white pine, and ponderosa pine are excellent for non-structural uses, such as triangular corner blocks, etc.

### THE FIRS (*Abies*)

Nine species are native to the United States and Canada. These are: balsam fir (*Abies balsamea*), Fraser fir (*A. frasier*), subalpine fir (*A. lasiocarpa*), Pacific silver fir (*A. amabilis*), grand fir (*A. grandis*), white fir (*A. concolor*), noble fir (*A. procera*), California red fir (*A. magnifica*), bristlecone fir (*A. bracteata*), a rather small, inaccessible tree, not harvested (protected) in the California Santa Lucia Mountains.

The firs of suitable size and quantity for our use are noble fir, red fir, white fir, and to a lesser extent, grand fir and Pacific silver fir.

Fir wood is strong, lightweight, light in color, straight-grained, often fine-grained, and is easily worked. The absence of resin in the wood, as in spruce, lowers its durability rating, but certainly this can be corrected with preservatives, proper varnishing and proper storage of the airplane. Fir is relatively abundant and most often used for dimensional lumber, boxes, paneling, plywood core-stock, and was once popular for butter containers for its non-resinous factor. Though there are a number of colors associated with the names of some firs (red, white and silver) these are for either bark or foilage. Fir woods are visually indistinguishable except for grain density, basic weight and timber quality.

**NOBLE FIR** (*Abies procera*) is our premium "true fir". In fact, legend has it that noble fir was successfully substi-



(Photo by O. V. Matthews)

**FIGURE III: WHITE FIR (*Abies concolor*)** the most widely distributed important lumber fir in North America is harvested extensively; filmed near Klamath Falls, Oregon in the Cascade Mountains.

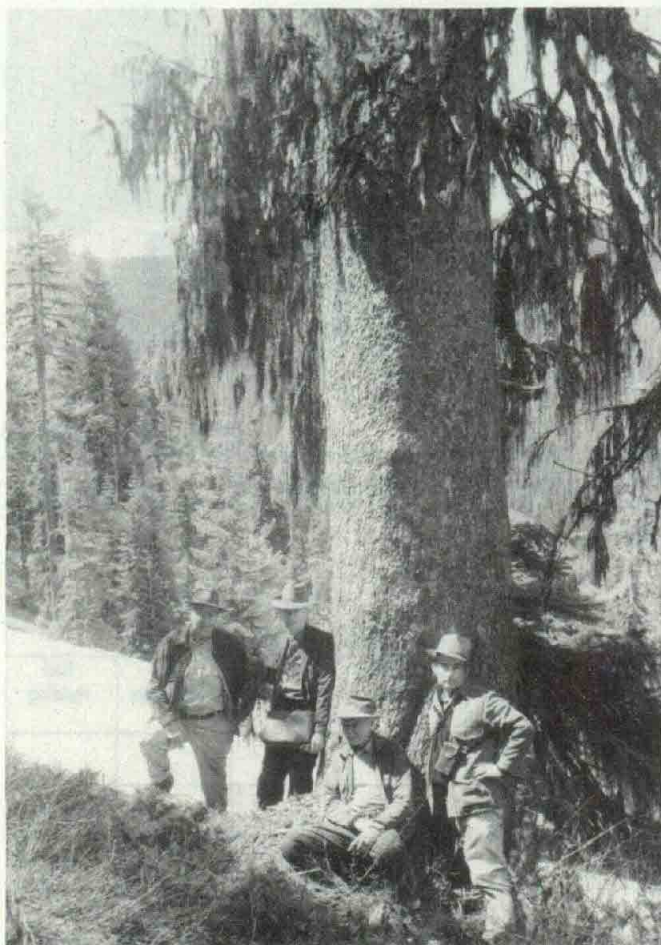
Wood Species	GRADING CODE:										
	1 - RELATIVELY HIGH					2 - INTERMEDIATE		3 - RELATIVELY LOW			
	Behavior And Working Traits					Strength And Load Features					
	Lightness In Weight When Dry	Resistance To Shrinking	Resistance To Warping	Working Ease	Resistance To Decay	Bending Strength	Rigidity	Columnar Strength	Hardness	Toughness	Nail Holding
Port Orford Cedar	2	1	1	1	1	2	1	2	2	2	2
Sitka Spruce	2	2	1	2	3	2	1	2	3	2	-
Western Hemlock	2	2	2	2	3	2	1	2	2	2	2
Noble Fir	1	2	2	2	3	2	1	2	3	2	2
Douglas Fir	2	2	2	3	2	1	1	1	2	2	2
Mahogany	2	1	1	1	1	2	2	2	2	2	2
Yellow Birch	3	3	2	3	3	1	1	2	1	1	1

TABLE I Adapted from AN 01-1A-7 A.P. 26754 Repair Handbook 1944

TABLE II

Wood Species	Weight Per Cubic Foot At 12% Moisture Content	Static Bending				Compression Parallel To Grain		Compression Perpendicular To Grain - Stress At Proportional Limit	Shear Parallel To Grain - Maximum Shearing Strength	Tension Perpendicular To Grain - Maximum Tensile Strength
		Stress And Proportional Limit	Modulus Of Rupture	Modulus Of Elasticity	Work To Maximum Load	Stress At Proportional Limit	Maximum Crushing Strength	Stress At Proportional Limit	Maximum Shearing Strength	Maximum Tensile Strength
		Limit Lb. Per Square-Inch	—————	1,000 Lb. Per Square Inch	In. - Lb. Per Square Inch	Lb. Per Square Inch	Lb. Per Square Inch			
Spruce Spp.	31	6,700	10,100	1,510	8.8	4,500	5,650	650	1,120	360
Western Hemlock	29	6,800	10,100	1,490	7.5	5,340	6,210	680	1,170	310
Port Orford Cedar	29	7,700	11,300	1,730	9.1	5,890	6,470	760	1,080	400
Douglas Fir	34	8,100	11,700	1,920	8.6	6,450	7,420	910	1,140	300
California Red Fir	27	7,200	11,200	1,590	9.5	—	5,290	850	1,050	350
Noble Fir	26	6,600	10,100	1,580	8.8	4,960	5,550	640	980	220
Pacific Silver Fir	27	6,200	9,400	1,530	9.3	4,660	5,550	490	1,050	—
White Fir	26	6,500	9,300	1,380	6.7	3,590	5,350	600	930	260
Alaska Yellow Cedar	31	7,100	11,100	1,420	10.4	5,210	6,310	580	1,130	360
Western Larch	36	7,900	11,900	1,710	8.0	5,950	7,490	1,080	1,360	310
Red Pine	34	8,400	12,500	1,800	10.0	5,330	7,340	830	1,160	490
Eastern White Pine	25	6,000	8,800	1,280	6.7	3,680	4,840	550	860	300

TABLE II Adapted from AN 01-1A-7 A.P. 26754 Repair Handbook 1944  
Based on extensive tests at the U.S. Forest Products Laboratory



(Photo by E. L. Parker)

FIGURE IV: BREWER SPRUCE (*Picea breweriana*) of limited occurrence at high elevations in a small area of southwestern Oregon and adjacent northwestern California, yields wood of high quality; filmed near Oregon Caves National Monument.

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tuted for Sitka spruce in British Mosquito Bombers during World War II. The wood is plentiful, of good quality, FPL rated and comparatively inexpensive. Its habitat is at higher elevations from the Cascade Mountains of central Washington through western Oregon to the Siskiyou and Klamath Mountains of southern Oregon, and to the Trinity Mountains in northwestern California (Humboldt County). In these southern limits it is more commonly called "Shasta fir" or "Shasta red fir" (but not to be confused with the *shastensis* variety of California red fir of the Sierra Nevada Mountains and the Mount Shasta region).

CALIFORNIA RED FIR (*Abies magnifica*) though probably not as plentiful as its close relative, noble fir, is of good quality and is also FPL rated. This fir occurs from Kern County (high elevations of the Sierra Nevada Mountains) northward, and in the highest coastal mountains of northern California, in the Mount Lassen and Mount Shasta region (Cascade Mountains), and thinly into the Cascade and eastern-most Siskiyou Mountains of southern Oregon, where some suspect intergrading with noble fir. The recognized variety Shasta red fir (*A. magnifica* var. *shastensis*) is not separated except by its cones; is indistinguishable in all other respects, and generally not noticed by foresters or lumbermen.

WHITE FIR (*Abies concolor*) is the most widely distributed commercially important (lumber) fir in the United States. Often cultivated as an ornamental, it occurs in the central and southern Rocky Mountains (typical-variety *concolor*) to the Pacific slope in Oregon and California (var. *lowiana*) and into northern Mexico, and as with noble and red firs, is of large size and plentiful. The Sierra Nevada and Cascade Mountains (to central Oregon) produce most white fir lumber.

At this point I should emphasize that commercial or dimensional lumber from all the true firs, at least in Oregon and California, is usually marketed as "white fir"; chiefly because of the very light color of the wood, as well as the established marketing practice. Therefore, if one



(Photo by W. R. Parker)

**FIGURE V: ENGELMANN SPRUCE (*Picea engelmannii*)** the common spruce of the Rocky and Cascade Mountains can yield excellent spruce lumber. This mature tree was filmed in the Cascade Mountains in Southern Oregon. Large tree in background is a Douglas fir.

wishes to select a given species such as noble fir, he must usually follow that species from its timber delivery source, through the sawmill and planing mill, grading and final delivery. Millworkers are only interested in separating true fir lumber from other conifers (Douglas fir, pines, cedars, etc.). In southern Oregon, where noble fir is most abundant and usually called "Shasta fir", sawmills also process white fir and grand fir, and all three are marketed as "white fir".

**GRAND FIR (*Abies grandis*)** is also called "lowland white fir", and found generally at lower elevations. It grows from the coastal regions of northern California, and Oregon and Washington northward into southern British Columbia, inland to western Montana, northern Idaho, northeastern Washington and northeastern Oregon. Where this fir meets with pacific-slope white fir (var. *lowiana*) many intergrades (hybrids) are found. No effort is made to separate the two, and all lumber is simply "white fir". Rather a fast-growing tree at lower elevations, the better trees for our use would probably come from the higher elevations of the Inland Empire region.

**PACIFIC SILVER FIR (*Abies amabilis*)**, named for its smooth, light-colored bark and silvery foliage, is not abundant; usually growing in mixed stands and probably seldom marketed by its name. A handsome tree of good size and quality, its habitat extends from extreme southeastern Alaska and coastal British Columbia south to the middle Cascade Mountains of Oregon, with tiny outpost occurrences on south in the Siskiyou and Marble Mountains of extreme northwest California.

Our other American firs, subalpine fir (*Abies lasiocarpa*), a western timberline tree, balsam fir (*A. balsamea*), and Fraser fir (*A. fraseri*) are comparatively small and would seldom yield lumber suitable for airplanes. Balsam fir, widely distributed in Canada, the Lake States and northern Appalachian Mountains is commonly harvested for pulp. Fraser fir of the southern Appalachian Mountains is closely related to balsam fir and once formed good timber stands. These three boreal forest trees are now important as Christmas trees, but have suffered devastating attacks from aphids and budworms in the 20th century.

**WESTERN LARCH (*Larix occidentalis*)**, the second-most widely distributed larch or "tamarack" in America, is apparently the only one that is FPL rated. Study of the tables shows that while very strong, probably more-so than any other American conifer, it is comparatively heavy. This larch attains excellent size, much more-so than does the more widely distributed "tamarack" (*L. laricina*) of the northeastern United States, Lake States, Canada, and Alaska. Interestingly, western larch is a rich source of Galactan, a water soluble gum concentrated in the lower part of the tree. This oleoresin can produce "Venice" terpentine and related products.

Study of the tables clearly illustrates that except for its selection for "aircraft" grading, Sitka spruce has very close rivals for our use. If only from the standpoint of economics, our other usable trees should eventually be recognized and more fully utilized. On the basis of durability, strength and weight, and in the order of my personal preferences, I would not hesitate to use any of the following in the construction of my own project:

1. Port Orford cedar
2. Alaska yellow cedar
3. Sitka spruce
4. Western hemlock
5. Douglas fir
6. Noble fir or red fir
7. Engelmann spruce
8. White fir
9. Red pine

#### Some Definitions

<b>DENSE GRAIN</b>	Generally with annual rings having equal thickness of spring-wood and summerwood, and usually harder and heavier than normal.
<b>INLAND EMPIRE</b>	That region generally including northern Idaho, western Montana, eastern Washington and northeastern Oregon; a slight extension of the Rocky Mountains into the Columbia Basin.
<b>OLD-GROWTH</b>	Trees of old age having annular rings close together as a result of retarded or past-prime development; resulting in "fine grain".
<b>PACIFIC SLOPE</b>	That region generally extending westward from the Sierra Nevada and Cascade Mountains of California, the Cascade Mountains of Oregon and Washington, and from the Rocky Mountains of British Columbia, to the Pacific Ocean.

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